ISI DS-130

Dual Stage Scanning Electron Microscope

ISI International Scientific Instrument, Inc.

A key to future industrial development is materials

We are currently witnessing a revolution in such industries as energy and semiconductor manufacture. These industries have expanded rapidly due in great part to the development of new materials. The importance of new material development will certainly continue to be at the heart of most of the innovations of the 80's.

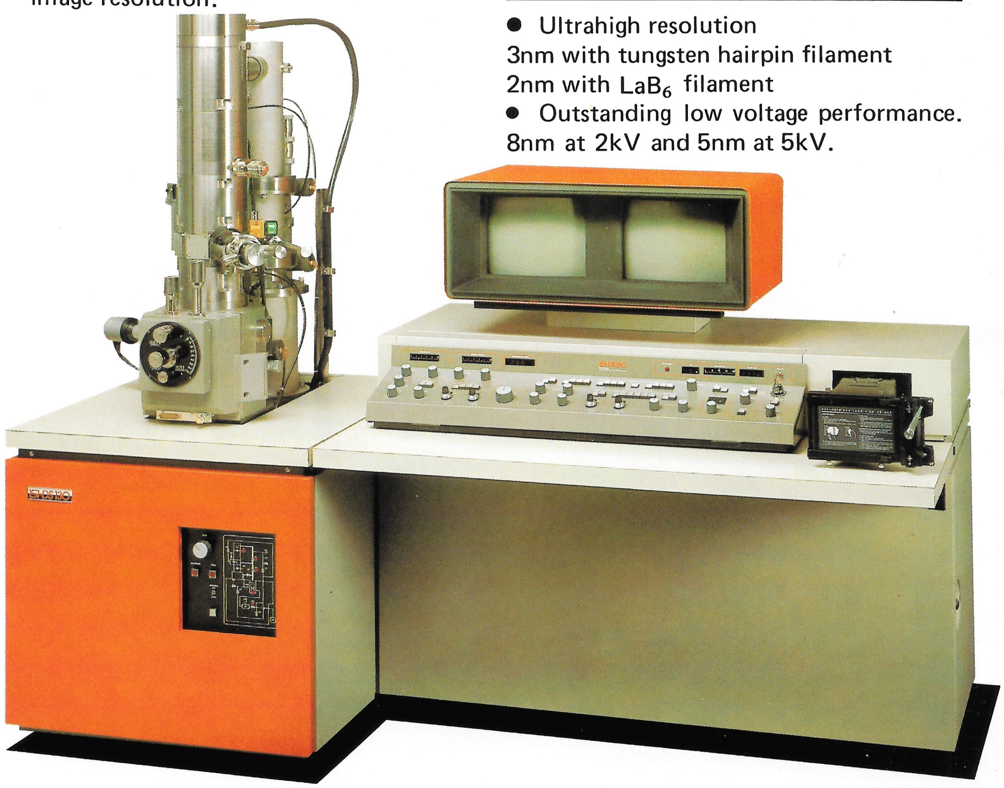
Comprehensive analytical capability is essential for the development of new materials

The properties of materials depend on such factors as composition, structure, defects, and texture. To determine the properties of new materials it is critically important to be able to evaluate the above characteristics. This requires a comprehensive analytical facility. Even in such fields as bioengineering an understanding of DNA recombination and gene splicing involves a detailed knowledge of cell and sub cellular.

Required capabilities of a new generation SEM

The following characteristics are critically important for an advanced SEM to meet the requirements of scientists during the coming decade.

a) Ultrahigh resolution, comparable to that of the most sophisticated field emission SEMs, but avoiding the characteristic emission instability of such systems, and the need for ultrahigh vacuum levels.
b) Flexibility must be provided in terms of sample handling, and various analytical tools must be compatible.
c) Qualitative and quantitative analysis of small areas on the order of 20nm must be possible.
d) A clean vacuum environment is essential to avoid specimen contamination and to allow the attainment of high image resolution.



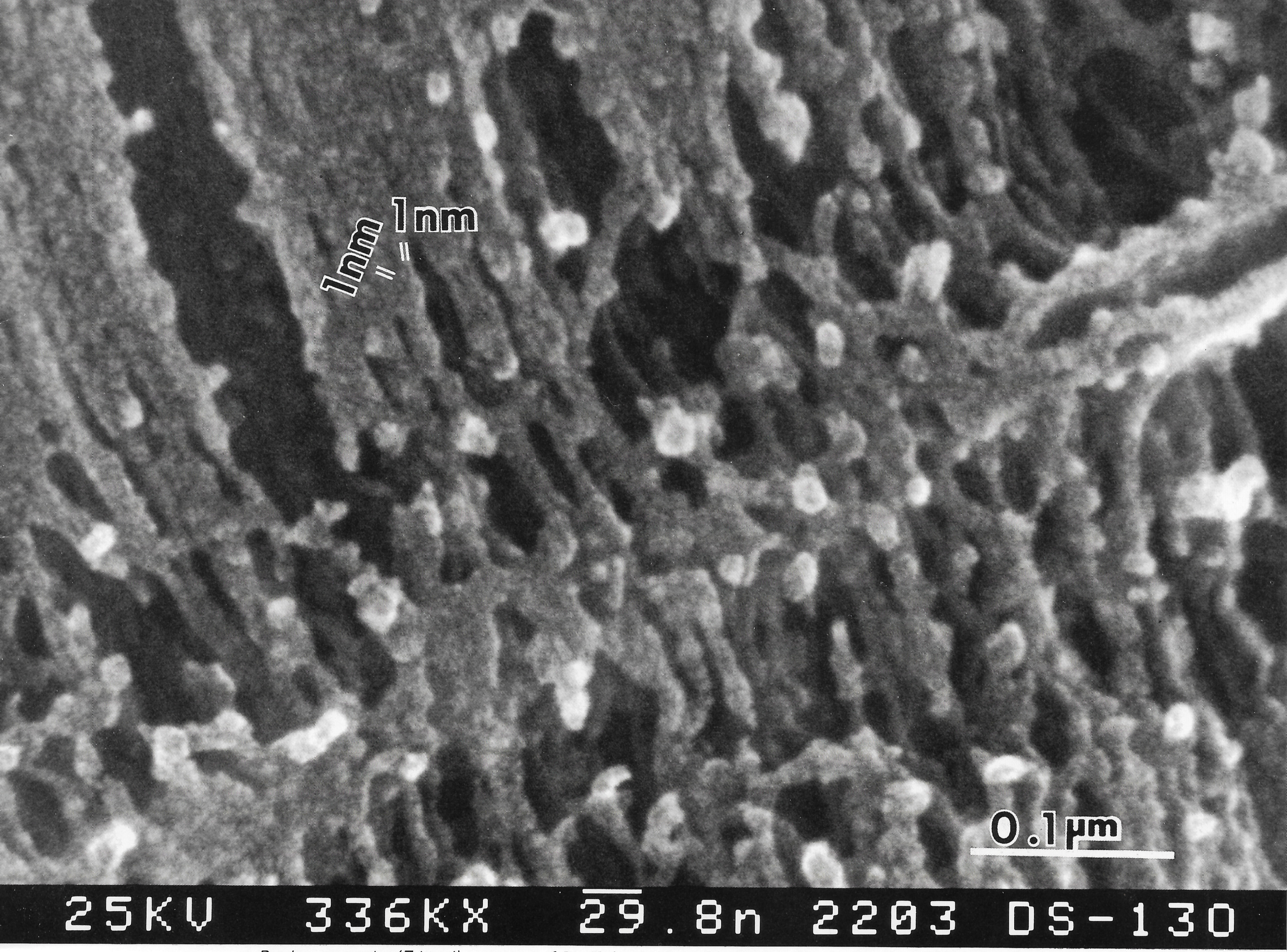
The DS-130 introduces a new era in scanning electron microscopy

The ISI DS-130 has been developed to meet the requirements of users both now and over the foreseeable future. This instrument is in a class by itself and employs technology much beyond that of conventional SEMs. It is in fact a new generation SEM.

DS-130 Features

- Ultrahigh resolution
3nm with tungsten hairpin filament
2nm with LaB_6 filament
- Outstanding low voltage performance.
8nm at 2kV and 5nm at 5kV.

The DS·130 SEM introduces new s
The leader in keen, discriminating



• *Rat heart muscles (Z band), courtesy of Dr. T. Inoue, Anatomy Laboratory II, Faculty of Medicine, Tottori University 336,000X (See Proceeding of SEM meeting 1982, Anaheim, U.S.A.)*

Low voltage produces images which are truly representative of the specimen surface and minimizes beam damage. These advantages are particularly valuable in biological and semiconductor application.

- When equipped with an EDX system, qualitative and quantitative analysis may be performed from areas as small as 20nm in diameter.
- By including two specimen stages with separate objective lenses, it has been possible to optimize the high resolution stage, especially from a vacuum and low contamination point of view. The bottom stage accommodates speciments up to 5" diameter and the mini lens allows high tilt angles at a short working distance.
- The high precision top stage is completely drift free and allows accurate specimen movement even at 200,000X magnification.
- The unique computer controlled five lens column design assures ease of operation and optimizes operating conditions throughout the voltage and magnification ranges.
- Clean high vacuum in the 10^{-7} torr range is obtained in the top stage. This results in minimum specimen contamination, which is essential for high resolution imaging and analysis.
- The vacuum system is fully automated, and includes both gun and column isolation valves. The high conductance design assures fast pump down and exceptionally clean vacuum.

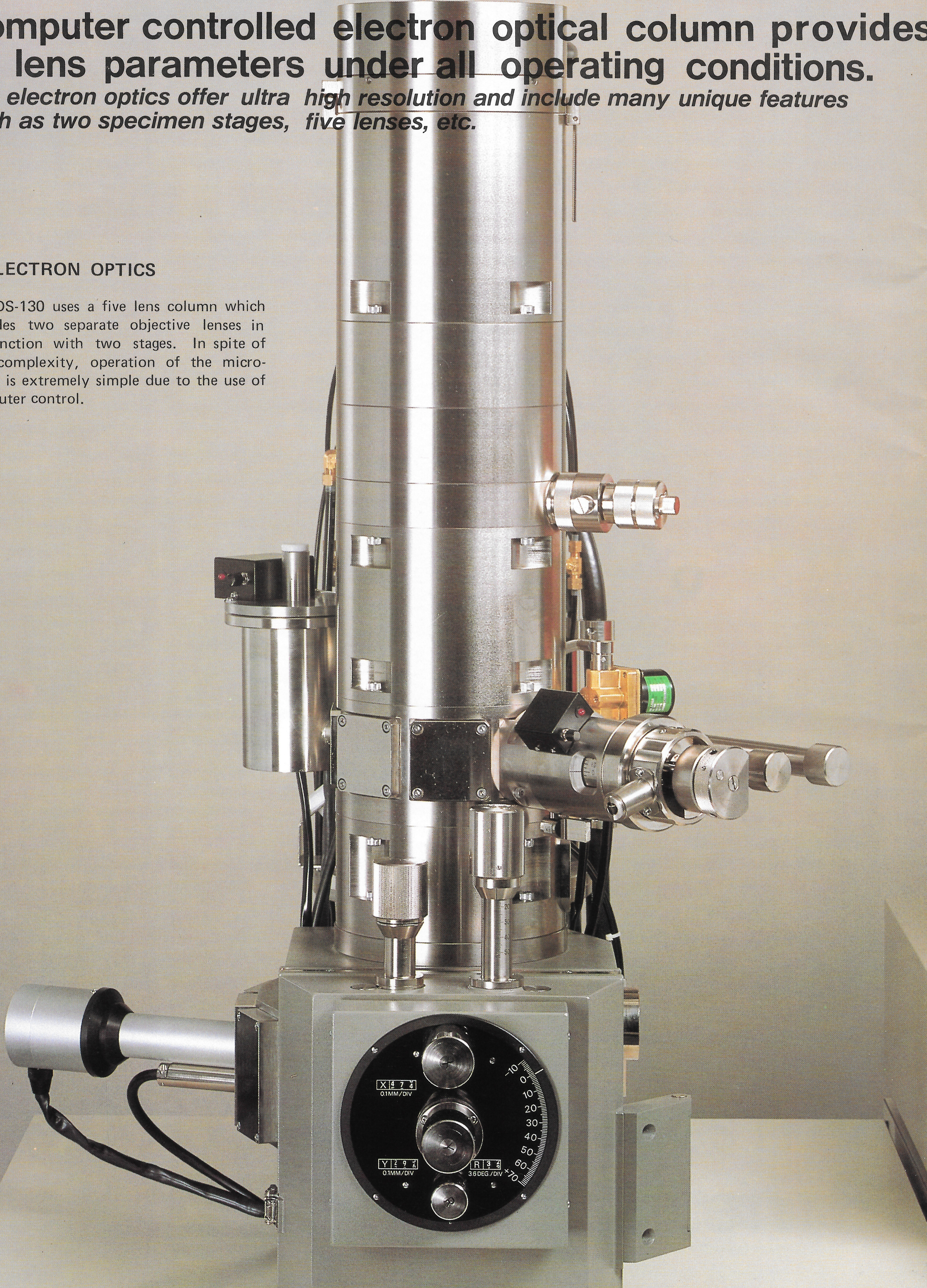
ght
2nm resolution.

Computer controlled electron optical column provides of lens parameters under all operating conditions.

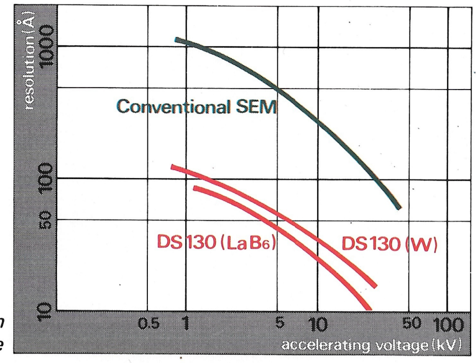
The electron optics offer ultra high resolution and include many unique features such as two specimen stages, five lenses, etc.

■ ELECTRON OPTICS

The DS-130 uses a five lens column which includes two separate objective lenses in conjunction with two stages. In spite of this complexity, operation of the microscope is extremely simple due to the use of computer control.



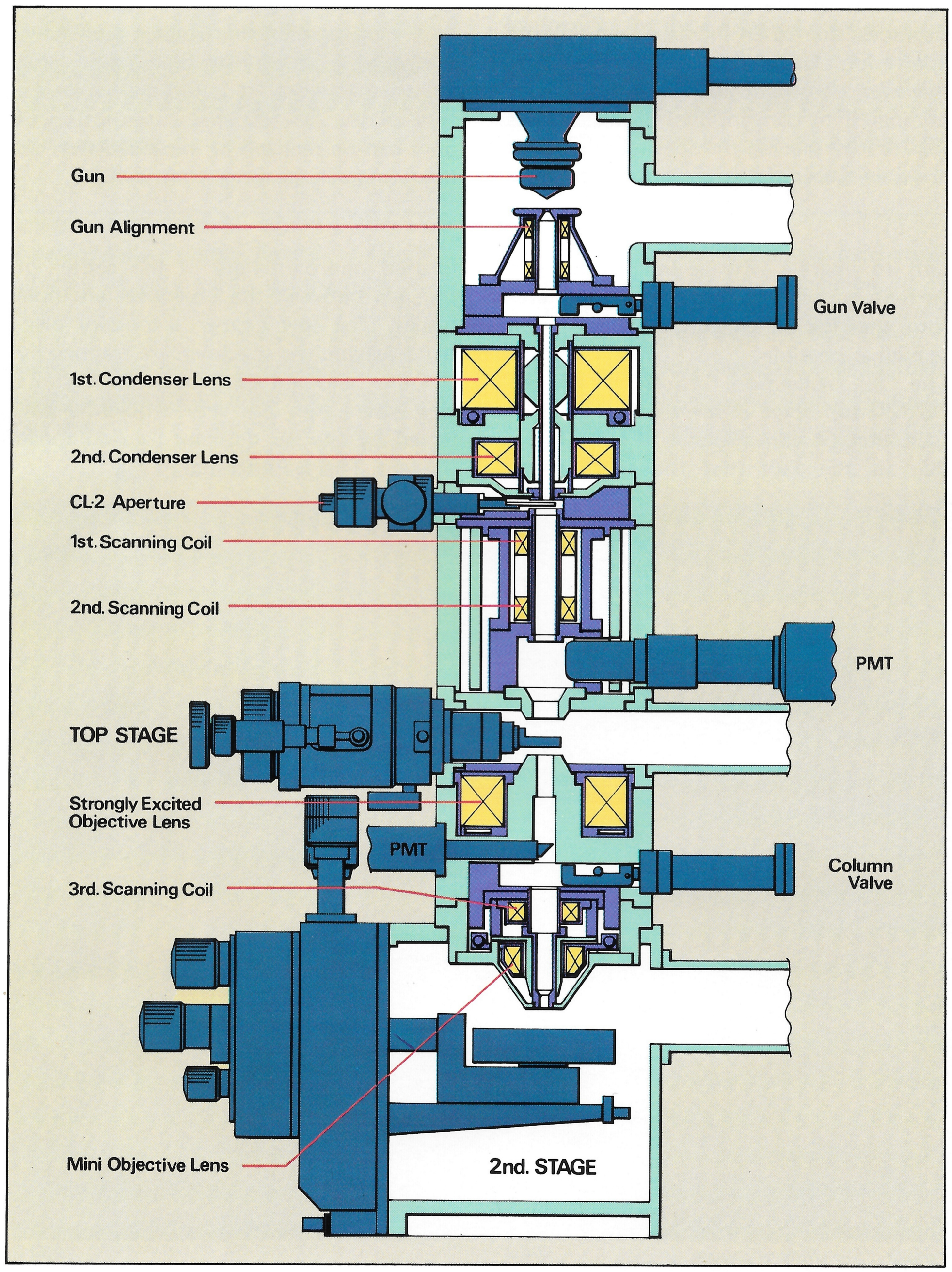
optimum adjustment



● *Relationship between high resolution and accelerating voltage*

Five Stage Electromagnetic Lens System

The first condenser lens has a double gap and single energizing coil. It is, in effect, two lenses. The second condenser is a single gap design. The first and second condenser lenses are used with both the top and bottom stages. A strongly excited objective lens is used only with the top stage and produces ultrahigh resolution. A mini objective lens is used only with the bottom stage and allows large specimens to be examined. As lens control is provided via a computer, it is extremely simple to switch from top to bottom stage operation and set up the optimum lens conditions throughout a magnification range from 10X to 300,000X. The magnification is indicated on an LED display and is fully compensated for all accelerating voltages and working distances.



CPU Control

In the DS-130 a number of parameters such as lens currents, stigmator currents, scan deflection, imaging signal gain, etc., are controlled by computer. This allows beam current and spot size conditions to be changed by simply pressing a button. Optimum conditions for high resolution imaging, low magnification observation, EDX analysis, etc., vary widely. The CPU automatically sets optimum parameters and considerably simplifies operation. A further advantage is that it is possible to dramatically reduce the number of electrical components in the electronics, thus enhancing overall system reliability.

Dual Objective Lens and Dual Stages

The DS-130 includes two completely separate specimen stages. The top stage is used for ultrahigh resolution and the bottom stage accommodates large specimens up to 5″ diameter. This allows the instrument to be used over a wide range of applications. To realize the conflicting requirements for high resolution and large specimen handling, two separate objective lenses are used — a strongly excited lens for high resolution and a mini lens for large specimen observation. The spherical and chromatic aberration coefficients of the strongly excited lens have been decreased to about a tenth of that of conventional SEM objective lenses. This is the principal reason why the DS-130 provides resolution of 3nm using a conventional tungsten hairpin filament.
When operating in the bottom stage, an extremely compact mini lens is used. This is particularly advantageous for the detection of x-rays, when operating at a short working distance. It also allows the examination of specimens twice as large as in a conventional SEM when tilted at 45° and at a working distance of 15mm.

ISI DS-130 ELECTRON OPTICS

■ High Resolution at Low Accelerating Voltage

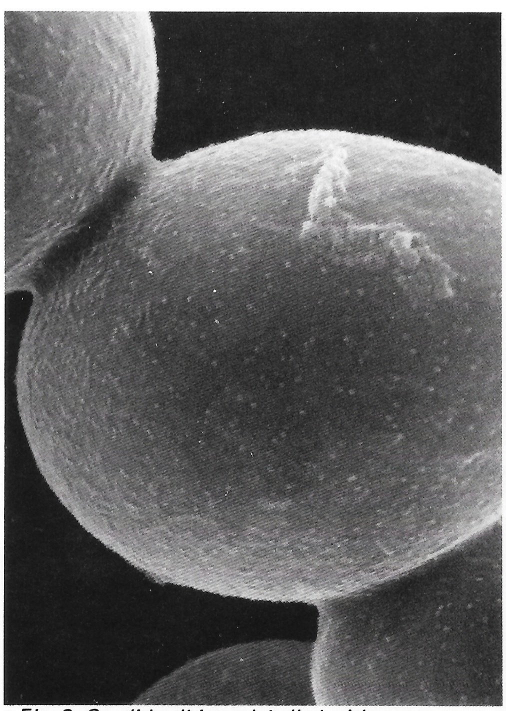
There has recently been an increasing demand for improved low voltage SEM performance, especially for biological and IC applications. This is required in order to produce an image more truly representative of the specimen surface, to eliminate charging, and to minimize specimen damage. The problem with low voltage operation of the SEM is that resolution degrades, due to an increase in chromatic aberration. Using the DS-130 top stage, however, chromatic aberration is very low compared to conventional SEM's. This is realized by placing the specimen between the pole pieces of a strongly excited objective lens. Secondary electrons are very efficiently collected by a detector located above the lens. Resolutions of 8nm at 2kV and 5nm at 5kV are quite routinely realized. This feature of the microscope will be particlarly important for future applications.

The guaranteed resolution for conventional SEMs applies when operating at maximum accelerating voltage and deterorates very rapidly as the accelerating voltage decreases. It is a remarkable feature of the DS-130 that a resolution of 5nm can be realized or exceeded over an operating voltage range from 5-40kV.

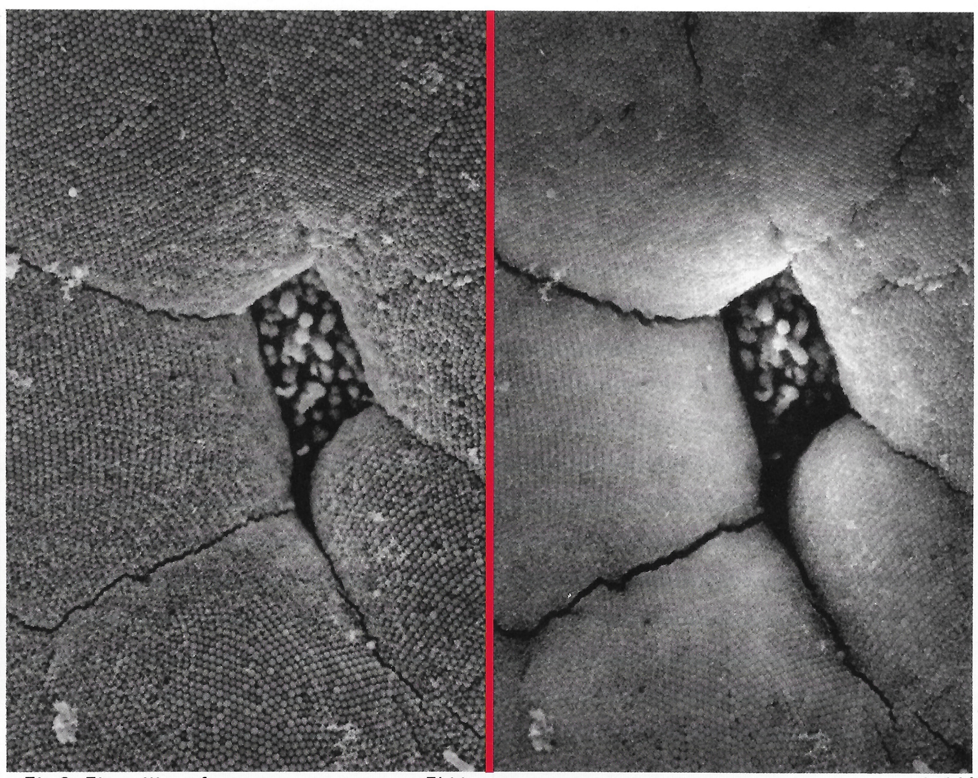
High S.E. Detection Efficiency and Minimized Specimen Damage

The importance of low voltage SEM operation is now receiving recognition in a number of materials science fields and in biology. Even at low beam energies some damage can occur, and it is important to operate with as low a specimen current as possible. It is important therefore, that the SE collection efficiency be as high as possible.

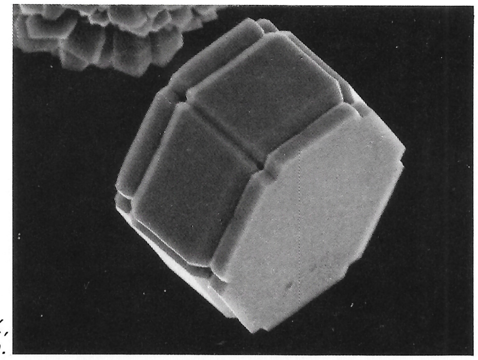
The SE collection efficiency of the DS-130 top stage is several times higher than that of conventional SEMs. This is due to the fact that the specimen is located approximately at the center of the gap between the objective lens pole pieces. The low energy secondary electrons leaving the specimen are trapped by the lens field and spiral back through the lens where they are very efficiently collected by the SE detector located above the lens. This is illustrated in Fig. 1.



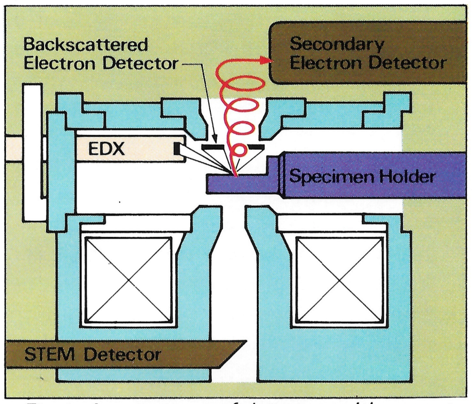
• Fig. 2 Candida albicans labelled with single ferritin.
Courtesy of Professor J. Tokunaga, Faculty of Odontology, University of Kagoshima, Japan.



• Fig.3 Fine villus of mouse small intestine (uncoated) 5kV 25kV



• *Uncoated single crystal magnesium powder 5 kV, 6,000X, courtesy of Professor R. Ueda, Meijo University, Japan.*



• *Fig. 1 Arrangement of detectors with respect to the top stage*

Figure 2 shows the secondary electron image of a candida albicans specimen labeled with single ferritin. Candida albicans is very easily damaged by electron bombardment. This photo was taken using a specimen current of $3x10^{-13}$ amps. It has been extremely difficult to observe this type of specimen in the SEM, but the unique features of the DS-130 eliminate the problems. This is one example of the advantages of the excellent low voltage resolution and high SE collection efficiency of the instrument.

Image Contrast at Low Accelerating Voltage

In order to observe the true surface microstructure of a specimen, it is necessary to use as low an accelerating voltage as possible for the following reasons.

a) At accelerating voltages above about 15kV, the incident electrons penetrate far into the specimen. Backscattered electrons produce SEs on leaving the specimen. This sub-surface signal causes degredation of the contrast in the image.

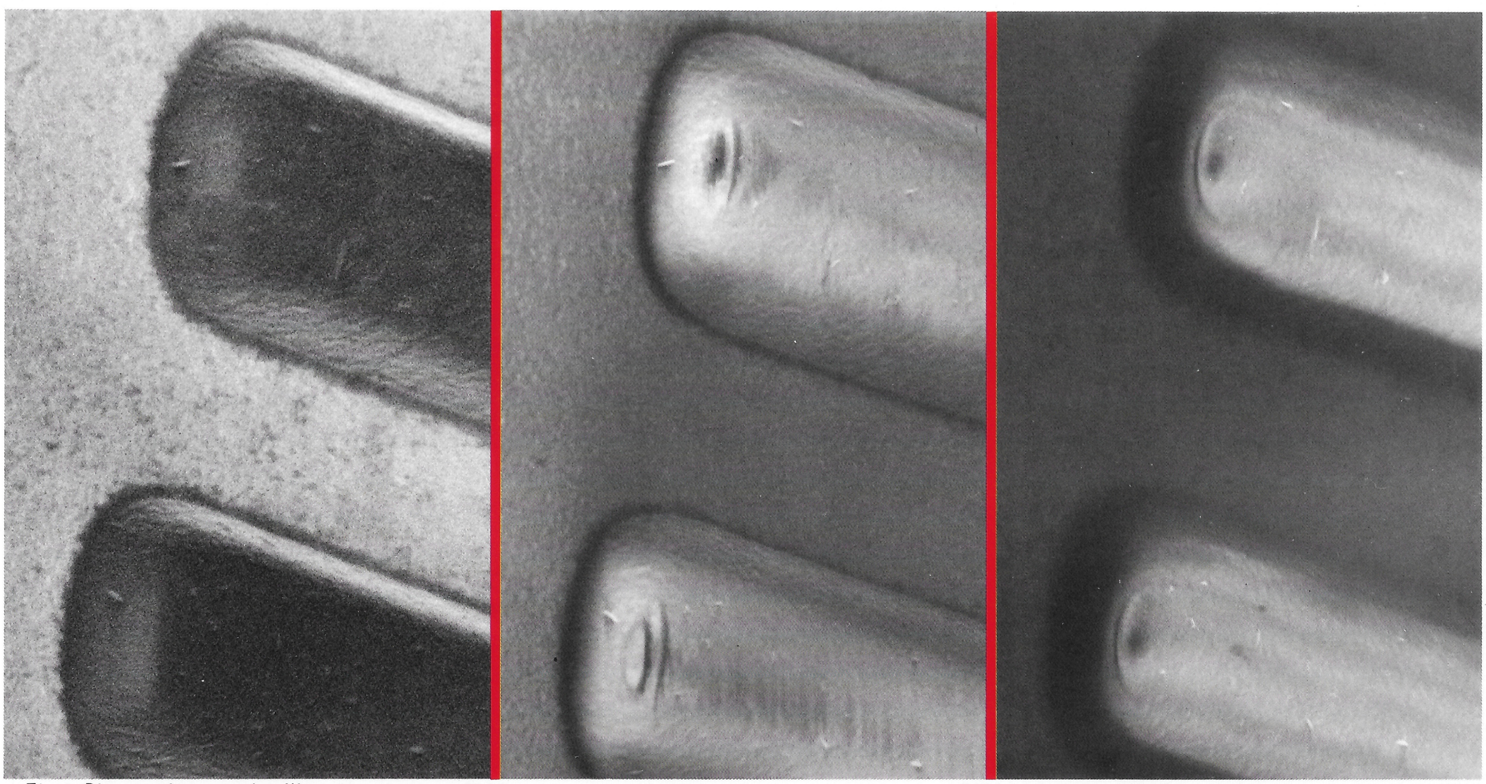
b) In order to observe the microstructure of a non-conducting specimen, it is necessary to coat the specimen with a thin conducting film. To preserve surface detail, it is necessary that the film be thinner than about 5nm. Platinum or platinum palladium have been found to be suitable coating materials. With such a thin film, charging will occur at high accelerating voltages, so low voltage operation is essential. In some situations it is necessary to observe a non-conducting specimen completely uncoated. This necessitates operating below 5kV.

Figure 3 shows a micrograph of the surface of a mouse intestine conductive stained with osmium-tannic acid osmium. This clearly shows that a much better contrast is realized at 5kV than at 25kV.

Truly Representative Image of the Specimen Surface

It is critically important that the next generation of SEMs be capable of producing high resolution images with high contrast at low accelerating voltages. The DS-130 is the only SEM available today that satisfies these requirements.

Figure 4 shows a series of micrographs of uncoated photo resist taken at 1,2, and 5kV. Note the charging effects at voltages above 1kV.



• *Fig.4 Photoresist on poly-silicone* 1kV 2kV 5kV

ISI DS-130 ELECTRON OPTICS

■ Ultra-high Resolution Assured at All Times

By using a strongly excited objective lens with very small aberrations, the DS-130 delivers image resolution of 3nm using a conventional tungsten hairpin filament. To ensure this performance level at all times, and on a routine basis, the following areas have received particular attention:

a) A high vacuum is maintained in the top stage area, thus minimizing specimen contamination.

b) A high precision, drift free stage is used, which allows accurate stage positioning at magnifications up to 200,000X.

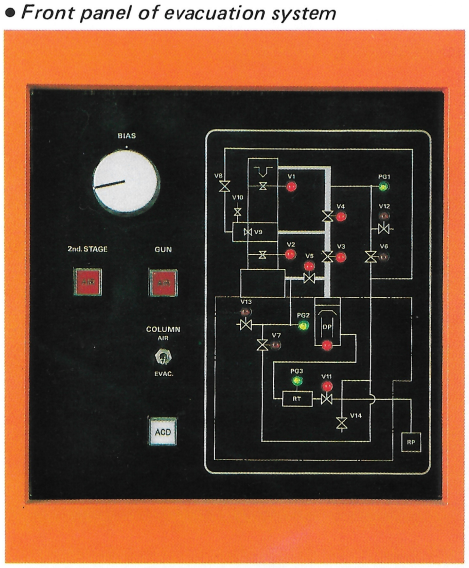
c) Highly stabilized lens current and high voltage supplies are used.

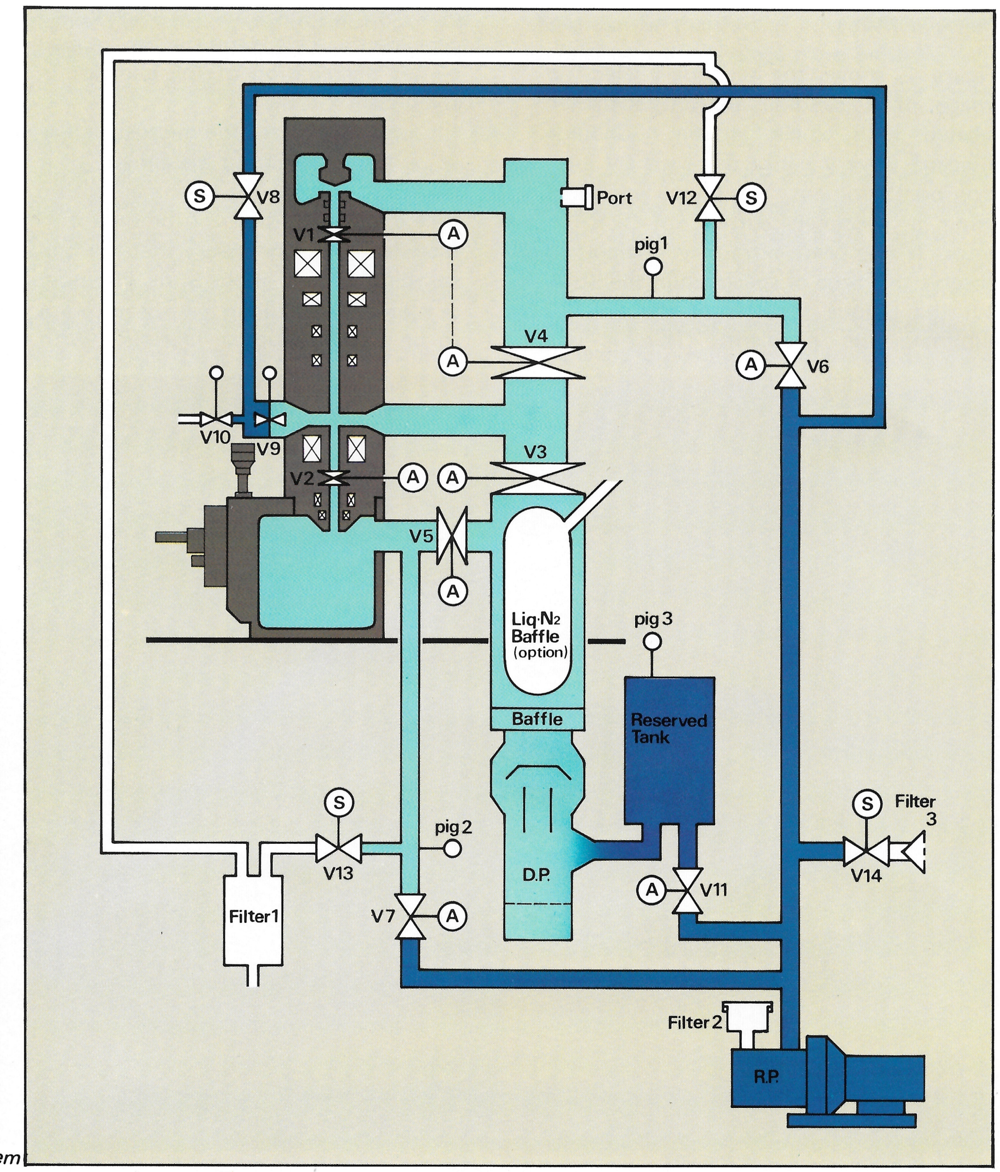
d) A sophisticated and very effective anti-vibration system isolates the electron optical column from the environment.

Clean High Vacuum

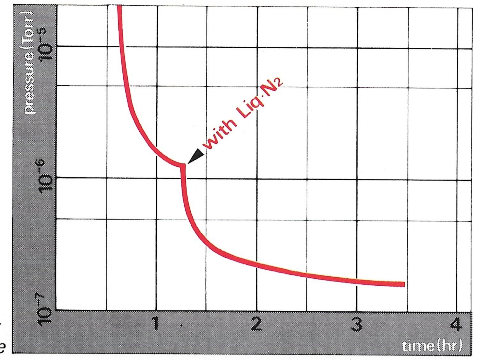
Specimen contamination in a SEM is detrimental, as it lowers the SE emission, and covers up fine surface detail. It is absolutely essential in a high resolution SEM that specimen contamination be kept at a minimum. As it is often necessary in a SEM to examine large specimens, it is necessary to provide a large specimen chamber and large, rather complex, specimen stage. Due to the large evacuated volume and outgassing of stage components, it is very difficult to realize a good clean vacuum on a routine basis. To overcome these problems the DS-130 is equipped with two chambers and stages. The high resolution chamber and stage

● *Front panel of evacuation system*





● *Schematic diagram of evacuation system*



• *Fig.5 Pumping characteristics of high-resolution top stage*

offers an exceptionally clean vacuum, due to the following design points:

a) The bottom chamber is automatically valved off when the top stage is used. This significantly decreases the volume which has to be evacuated.
b) Outgassing of the bottom stage does not affect the top chamber when it is being used.
c) A liquid nitrogen cooled trap in the top chamber collects contaminants and acts like a cryopump, thereby improving the vacuum level.
d) The column bore is maintained under vacuum and a liner tube without 'O' rings is provided. Lens coils and scan coils are all located outside the vacuum.
e) Great care was taken in the design of the pumping system. A high speed (600 1/sec) diffusion pump is used, which operates with an extremely low vapour pressure oil (10^{-10} Torr). This can be equipped with a liquid nitrogen baffle. A reservoir tank is located between the mechanical roughing pump and diffusion pump. Back-streaming of oil from the rotary pump is prevented by minimizing the roughing pump cycle and switching to the diffusion pump at about 10^{-1} Torr.

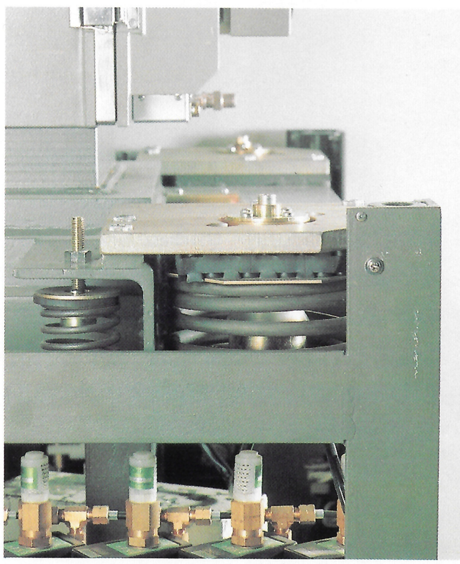
Due to these design features, an exceptionally clean high vacuum of 2×10^{-7} Torr (2.67×10^{-5} pa) is obtained in the top chamber for high resolution operation. A vacuum of 5×10^{-6} Torr (6.67×10^{-4} pa) is obtained in the bottom chamber. A fully automated pneumatic valving system assures rapid and fail-safe operation.

Vacuum Characteristics

Figure 5 shows the vacuum characteristics of the top chamber after swiching the instrument on. 1×10^{-6} is reached in 90 minutes without the LN_2 cooled anticontamination trap. Cooling the trap at this point increases the pumping speed, and a vacuum of 2×10^{-7} Torr is reached after an additional hour of pumping. As an airlock is provided for the top stage, the chamber can be maintained under vacuum at all times, so that vacuum levels in the 10^{-7} Torr range are routinely obtained within a short time of specimen exchange.

Anti-Vibration Mounts

A sophisticated vibration isolation/damper system is used on the DS-130. This is very effective in isolating the column from any high frequency vibrations. An oil damper rapidly attenuates any large amplitude vibrations. The high resolution top stage is a very rigid construction, and is therefore rather insensitive to low frequency vibrations. The net result is that micrographs can readily be taken at magnifications up to 300,000X completely free of any vibration effects.



• *Anti-vibration mechanism*

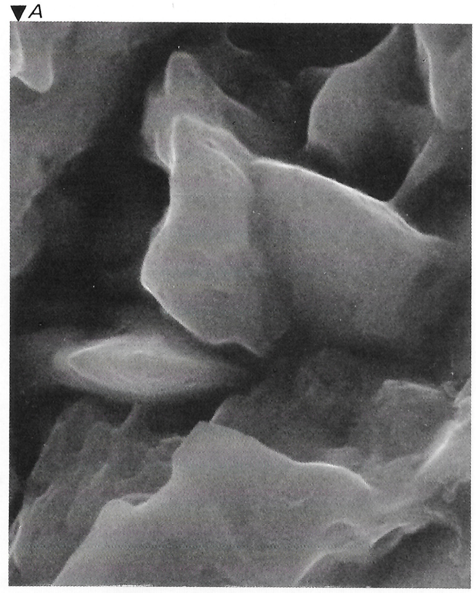
Total System Stability

The resolution of conventional SEMs is about 6nm. This is about 20 times poorer than the resolving power of a modern high performance TEM. To date, there has been little attention paid in SEMs to areas such as high voltage and lens current power supply stability, specimen contamination, and stability of the system over long periods of time, which are critically important for TEMs. As the resolution of SEMs improves, however, it becomes essential to adopt specifications similar to those of TEMs. The DS-130 uses high voltage and lens current power supplies stabilized to 10^{-6}, which is similar to high performance TEMs. Specimen contamination is also comparable, as are the zero drift characteristics of the top stage. For these reasons 3nm resolution with a standard tungsten hairpin filament is obtained routinely over long periods.

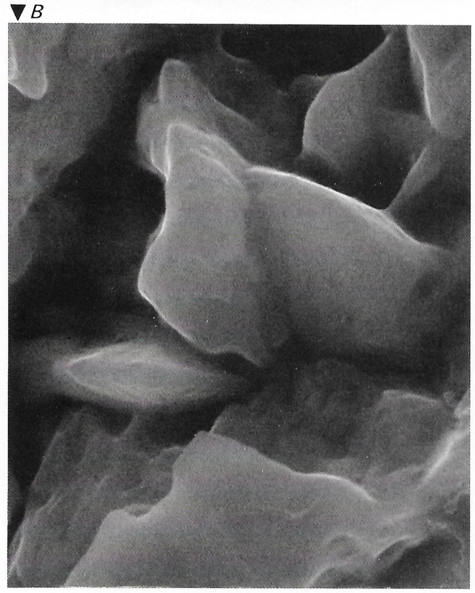
Figure 6 shows two micrographs of the same area of a gold mesh sample. Photo (B) was taken 50 minutes after Photo (A) without adjusting focus. Comparison of the two micrographs shows neither focus change nor specimen drift.

• *Fig.6 Gold mesh*

▼*A*



▼*B*

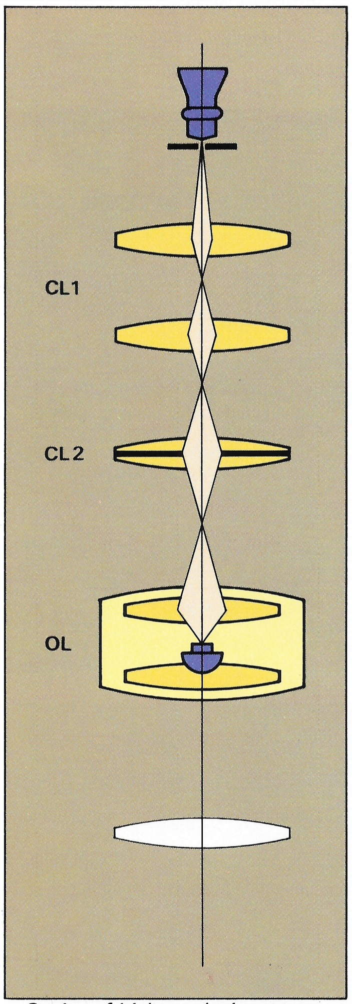


ISI DS-130 ELECTRON OPTICS

■ A Wide Variety of Imaging and Analysis Modes

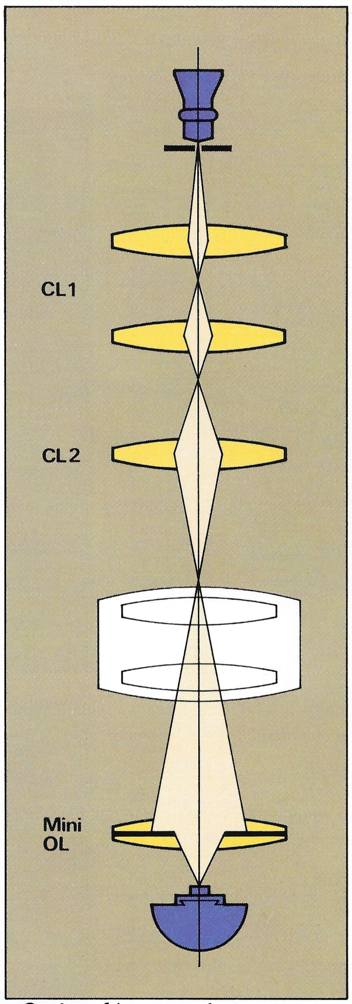
Due to the use of a dual stage system, the DS-130 allows optimum qualitative and quantitative x-ray analysis to be performed, as well as producing S.E. image resolution of 3nm, using a conventional tungsten hairpin filament. In addition, various other types of imaging are possible, such as backscattered electron, high resolution STEM, EBIC, voltage contrast, specimen current, and cathodolumine-

TOP STAGE



• *Optics of high-resolution top stage*

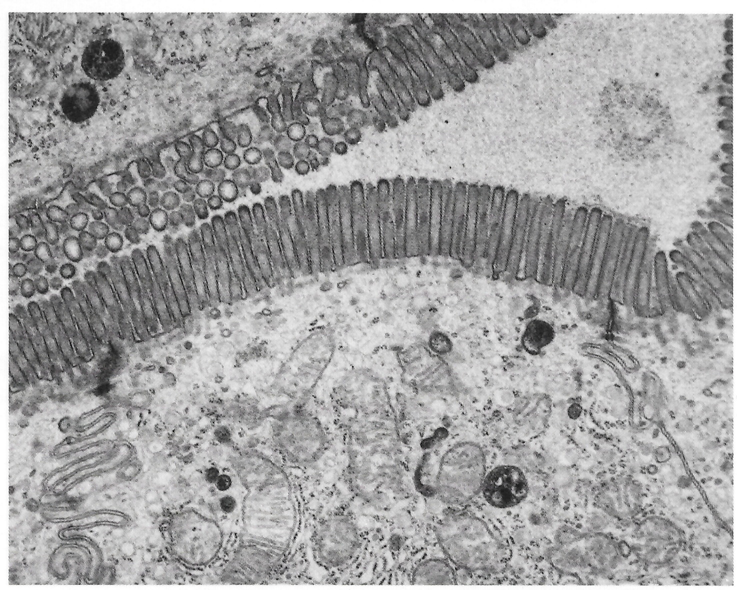
2nd. STAGE



• *Optics of large-specimen stage*

Secondary electron image

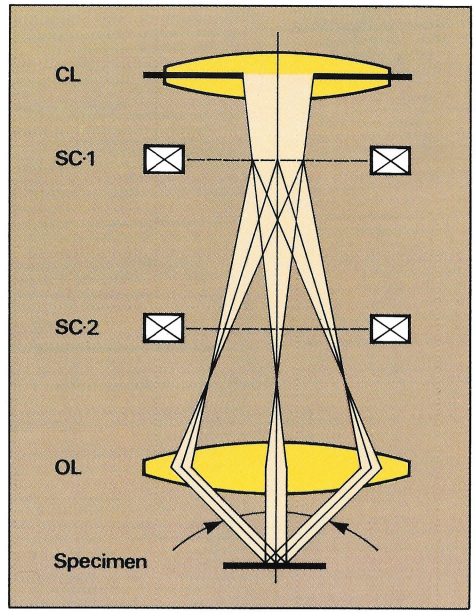
• *Mouse glomerules 9,500X*



STEM image

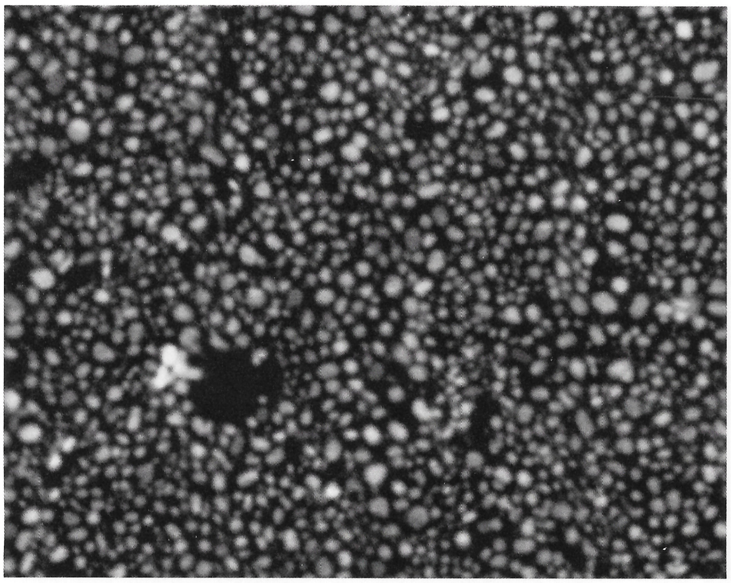
• *Mouse small intestine 10,000X*

scence. Electron channeling patterns can be obtained from areas as small as 3 microns, and elemental analysis can be performed on areas down to 20nm. The ultrahigh resolution of the DS-130 sets it apart from all other SEMs, and this is the fundamental starting point for all subsequent analysis steps.



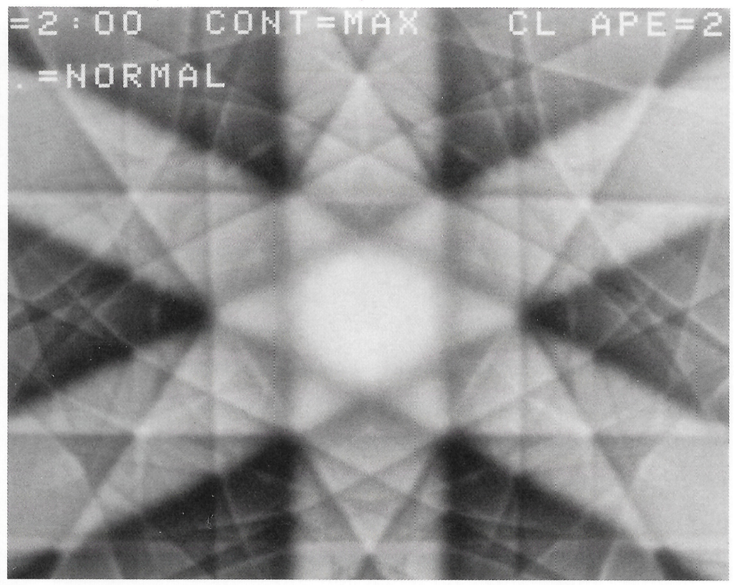
Backscattered electron image (Robinson detector)

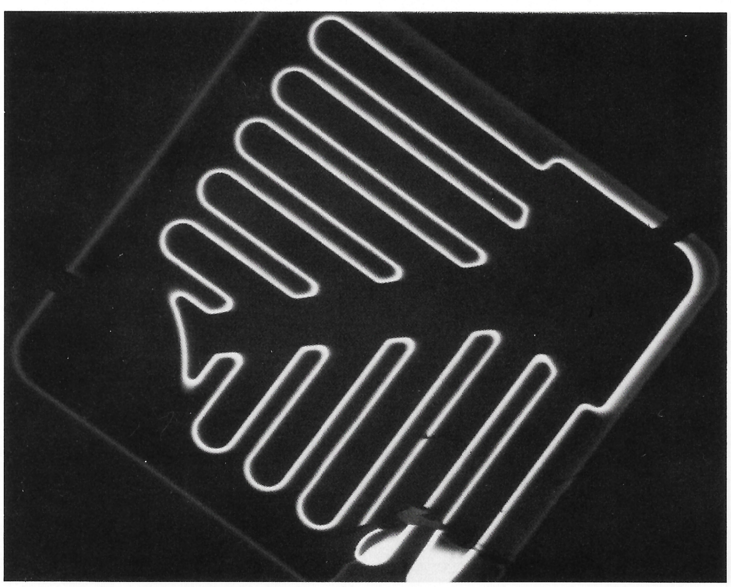
● *Deposited particles of gold on carbon 52,000X*



Electron channelling pattern image

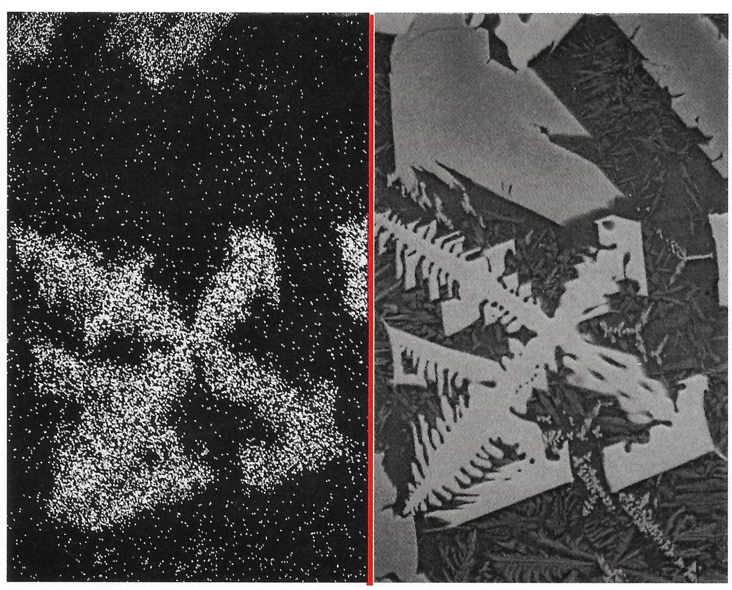
● *Silicon ⟨ 111 ⟩ pole*





EBIC image

● *EBIC image of transistor 60X*



Characteristic X-ray image (mapping)

● *TiKα X-ray image of iron slag from "tatara buki" furnace and BSE image, courtesy of Professor T. Takahasi, Tokyo Institute of Technology*

Unique Dual Stage System-Top Stage Provides Ultrahig Bottom Stage Accommodates Specimens up to 5″ Diar

High resolution and large specimen handling capability are usually unavailable in the same SEM. The DS-130 realize 3nm capability by virture of its low aberration objective lens and top stage design. Large specimens or multiple specimens can be viewed in the lower chamber. Versatility is retained and performance is not compromised.

TOP STAGE

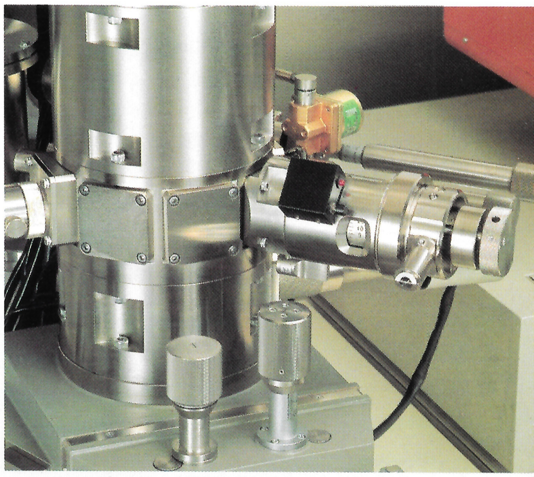
High Resolution Stage

A high resolution specimen stage for a SEM has a number of specific requirements which are of much less importance in a general purpose SEM stage. The following characteristics are of particular importance — highly precise stage movements, extreme insensitivity to vibration, and complete absence of stage drift at any setting. The latter feature is particularly important if advantage is to be taken of long exposure times, which may be required for ultrahigh resolution. To satisfy these requirements the DS-130 uses a unique eucentric side entry design, which incorporates some features found only on high precision TEM stages.

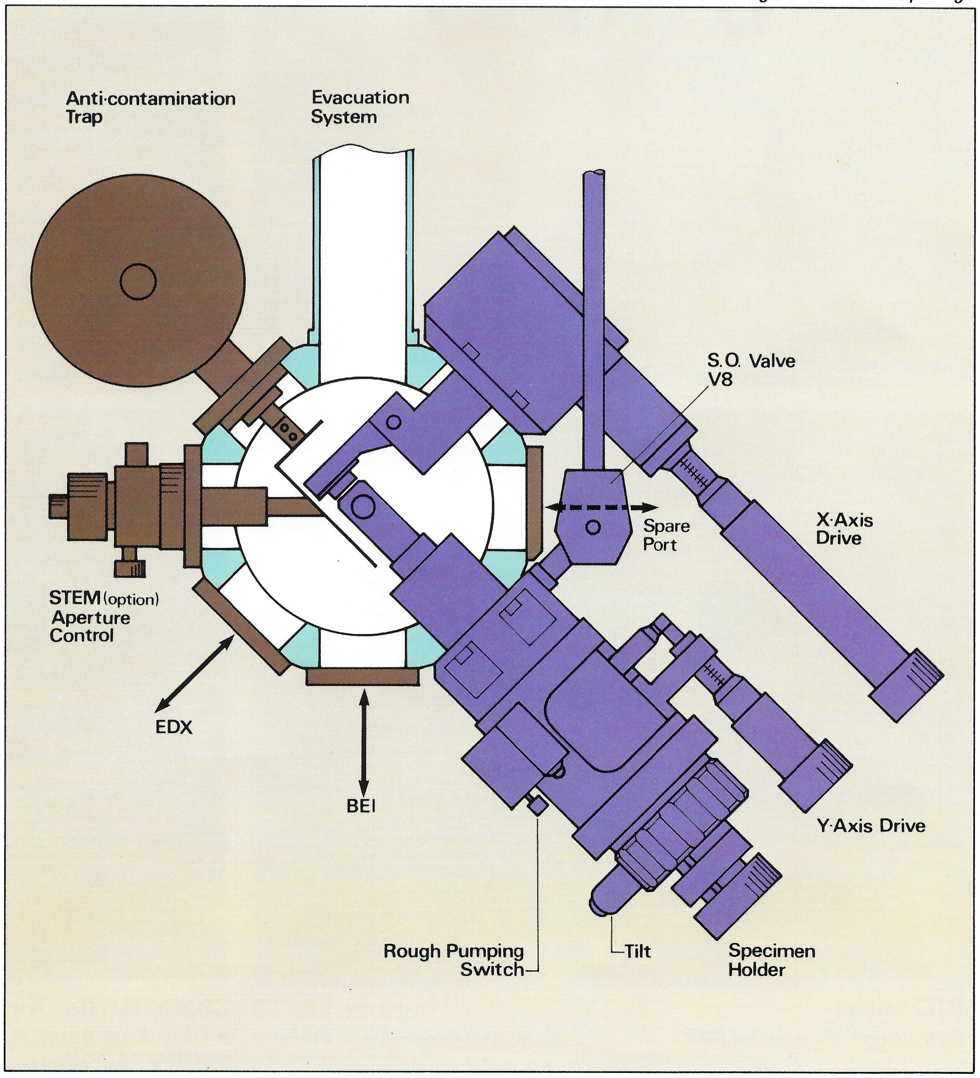
a) Very exact stage movement is accomplished using a micrometer screw and lever principle on both the X, Y drives, instead of gears. Backlash is effectively eliminated, and fine stage movements can be readily made at magnifications as high as 200,000X. .
b) The specimen surface can be set to coincide with the tilt axis, thus minimizing image shift on changing tilt angle.
c) By proper location of fulcrum points, choice of materials, etc, it has been possible to lower specimen drift to about one tenth that of conventional SEM stages.
d) The stage accommodates specimens up to 10mm diameter x 10mm thick. X, Y movement is 6mm, and tilt can be varied from -5° to $+95^\circ$.
e) The specimen chamber is provided with a total of 8 ports located at equal intervals around the chamber wall. Two ports are occupied by the specimen stage, and a third by a vacuum manifold. The additional ports can accommodate such devices as an anti-contamination device, EDX detector, STEM aperture, or backscattered electron detector, thus allowing the full analytical capabilities of the instrument to be realized.

In addition to the standard high resolution stage described above, a Z-prime stage, including a linear movement at right angles to the plane of tilt, is available. This is particularly useful when examining rough samples. It allows all parts of the specimen to be brought onto the eucentric tilt plane, thus eliminating image shift when changing the tilt angle. This stage has the same characteristics of high precision movement and zero specimen drift as the standard stage.

A number of different types of specimen mounts and specimen holder rods are available, as shown on the opposite page. These holder rods can be used with either the standard or optional Z-prime stage.



● *Cross-sectional view of high-resolution top stage*



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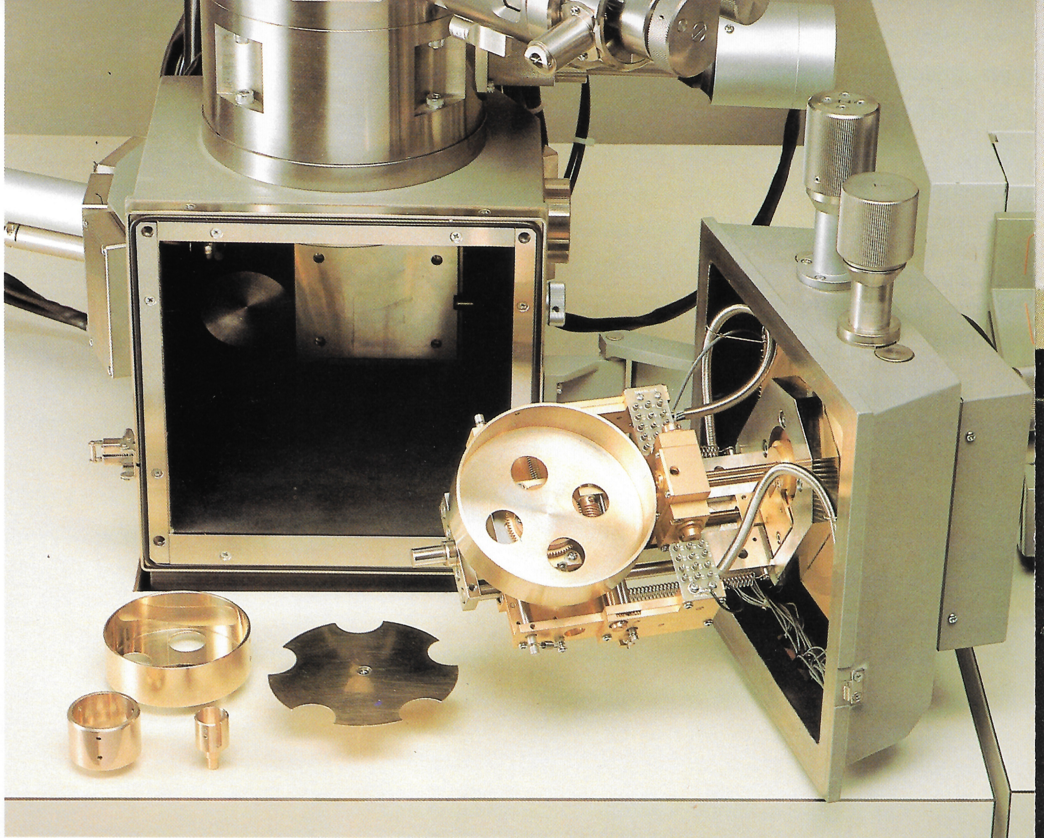
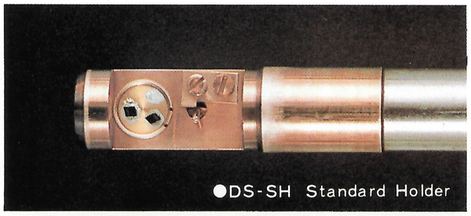
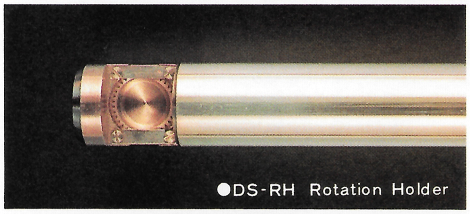
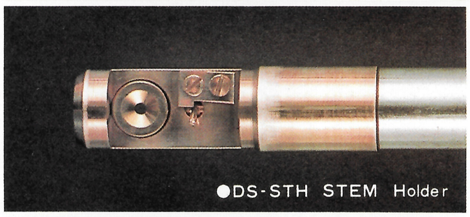




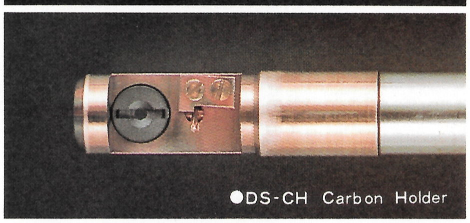
●DS-SH Standard Holder



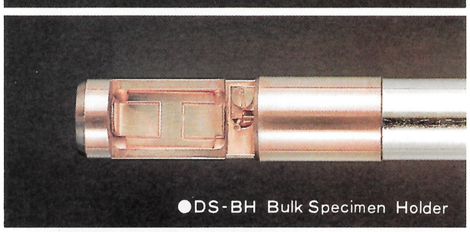
●DS-RH Rotation Holder



●DS-STH STEM Holder



●DS-CH Carbon Holder



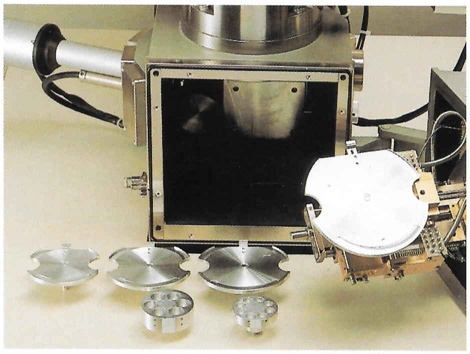
●DS-BH Bulk Specimen Holder

2nd. STAGE

Large Specimen Stage

There has been an increasing demand recently for large specimen handling capability in the SEM. This is required in particular to accommodate large semiconductor wafers and multiple specimens simultaneously. The standard DS-130 bottom chamber and stage allows the accommodation of specimens up to 5″, with observation of a full 4″ (102mm) diameter area. Eucentric tilt from −10° to +70°, 360° continuous rotation, and a working distance variable from 8mm to 53mm are provided. Specimen introduction and removal are particularly convenient, due to the hinged specimen chamber door arrangement which is used. The stage is equipped with a BNC connector, allowing measurement of the specimen current, and a 25 pin feedthrough and wiring harness for applying voltages to ICs.

The specimen chamber has five spare ports which are used for the attachment of a number of optionally available detectors such as EDX, BSE, cathodoluminescence, etc.



● *IC wafer holder*

● Top Stage Specimen Holders

Type of Holder	Specimen Size
● Standard holders	
Standard specimen mount	8mmϕ x 5mmt
Large specimen mount	8mmϕ x 5mmt
● Optional holders	
Rotation specimen holder rod	7mmϕ x 3mmt (360° rotation)
Grid holder for STEM★	3mm grid
Carbon STEM grid holder for EDX analysis ★	3mm grid
Large specimen holder rod	18mm x 8mm x 3.5mmt
Faraday cage holder rod	

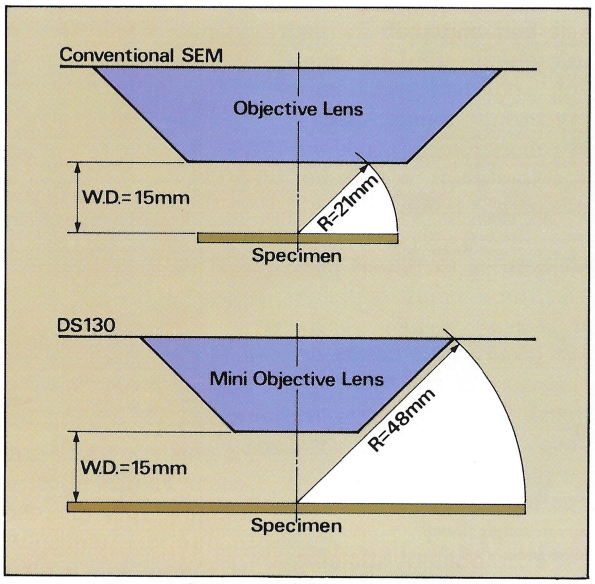
★ (used with standard specimen holder rod)

● Bottom Stage Specimen Holders

Type of Holder	Specimen Size
● Standard holders	
15mm holder	15mmϕ x 15mmt
32mm holder	32mmϕ x 25mmt
3″ holder	76mmϕ x 25mmt
4″ holder	102mmϕ x 25mmt
3″, 4″ wafer holder	102mmϕ x 0.5mmt
● Optional holders	
Multi-sample holder I (attaches to 15mm holder, accepts 6 top stage standard specimen mounts)	15mm x 15mm
Multi-sample holder II (attaches to 15mm holder and accepts 8 top stage standard specimen mounts)	10mm x 5mm
3″ wafer holder	77mmϕ x 0.6mmt
3½″ wafer holder	90mmϕ x 0.6mmt
4″ wafer holder	102mmϕ x 0.6mmt
5″ wafer holder	127mmϕ x 0.6mmt
4″ mask holder	102mmϕ x 2.5mmt
5″ mask holder	128mmϕ x 2.5mmt

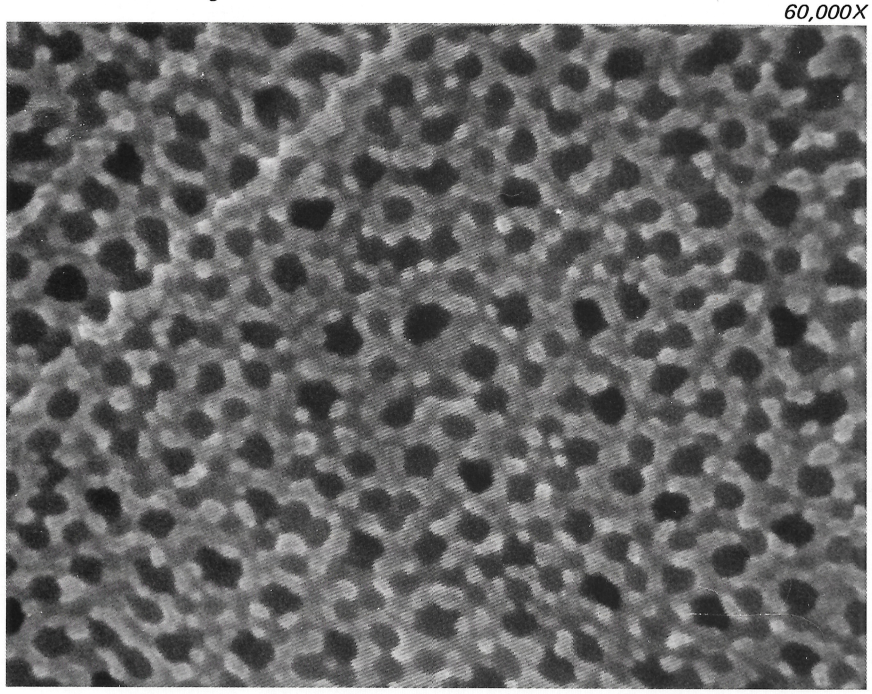
High Resolution Using Bottom Stage and Mini Lens

When using the bottom stage, the mini lens is used as the final focusing lens. This lens is designed to produce high resolution on large specimens tilted to high angles. At a working distance of 15mm, a 4" diameter specimen can be tilted to 45°. This short working distance allows high resolution images to be produced.
At a working distance of 8mm the resolution is guaranteed to exceed 6nm, and indeed resolutions of 5nm can be realized. The highly stabilized high voltage and lens current power supplies, which are so essential for the top stage operation, also contribute to good bottom stage performance. Figure 7 shows a micrograph of anodized aluminum taken in the bottom stage.

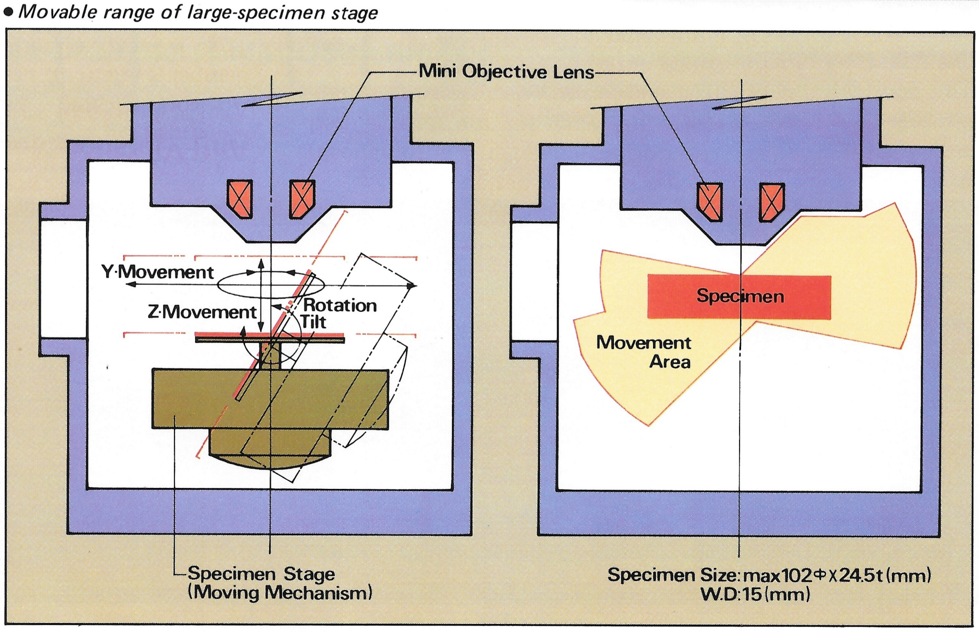


• *Compact mini lens vs conventional type of objective lens*

• *Fig.7 Oxide film of anodized aluminum 60,000X*



• *Movable range of large-specimen stage*

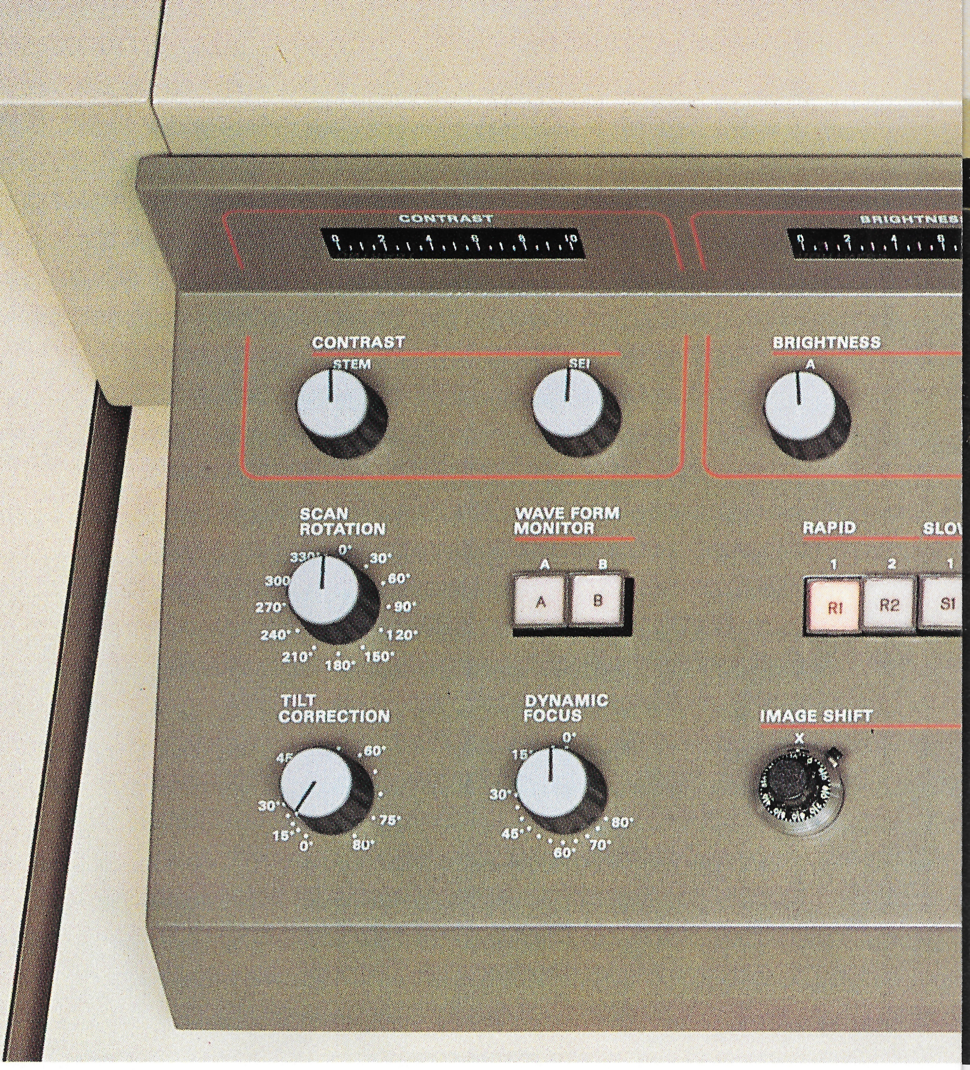


Space Around the Mini Lens is Useful for High Resolution Observation of Large Specimen

The very compact mini lens configuration allows large degrees of movement for bulky specimens at short working distances. By maintaining the working distance short, both chromatic and spherical aberration are minimized, thus allowing high resolution images to be produced both at high and low accelerating voltages.

Well Laid Out and Easy to Operate Control Panel

Excellent micrographs are easily and routinely obtained, even by inexperienced operators.



■ Controls

Logical and well thought out layout of controls on a SEM can enhance the efficiency of the instrument and avoid operational errors. The location and grouping of controls, as described below, results in rapid familiarization and simple operation.

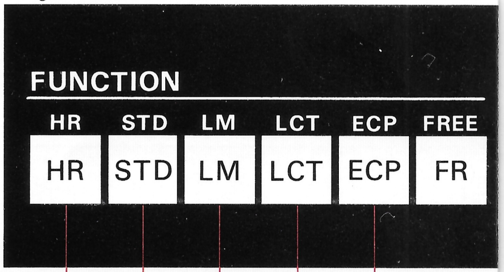
a) The most frequently used controls, such as magnification, focus, imaging mode, scan mode, etc., are located in the middle of the main control panel.
b) Electron gun controls, such as the high voltage on/off and select, filament current and filament imaging are grouped together at the right of the main panel.
c) Controls relating to raster control, such as scan rotation, tilt correction, dynamic focus, etc., are located at the left of the main panel.

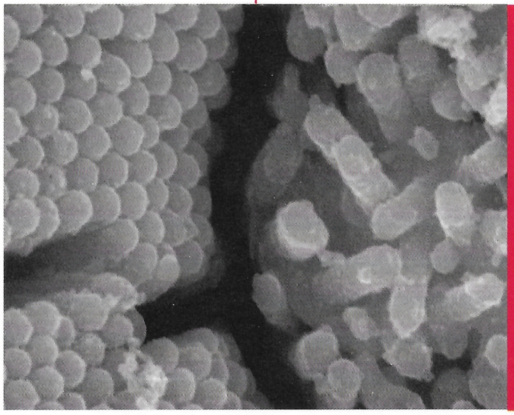
Controls used less frequently, such as Y-modulation, Gamma, derivative processing, etc. are located on a separate panel which has a cover, so that they can be kept out of the reach of inexperienced operators.

Consistent Performance Independent of Operator

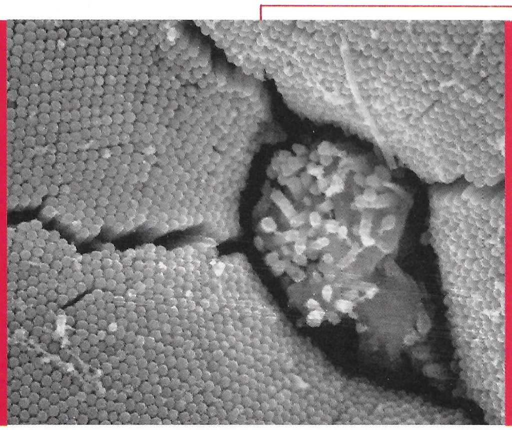
A series of push buttons allow the operating functions such as high resolution , standard mode, low magnification, large current, and electron channelling pattern mode to be selected rapidly. In each mode, and at all accelerating voltages, the correct lens current, spot size, and operating conditions are set up via computer control. Astigmatism correction is extremely simple, as image shift is eliminated by means of stigmator alignment controls. Astigmatism corrections are automatically applied on changing from one operating function to the other.
The contrast and brightness controls for photography can be set using the contrast and brightness LED display on the con-

• *Fig.8 Function mode*

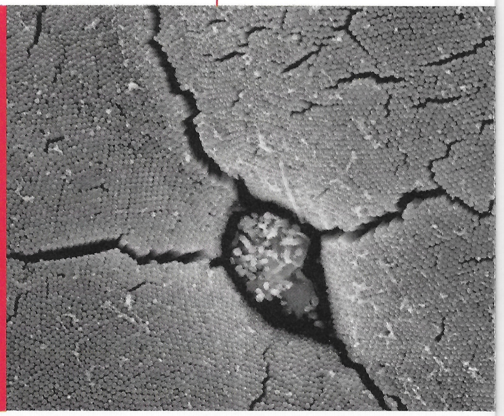




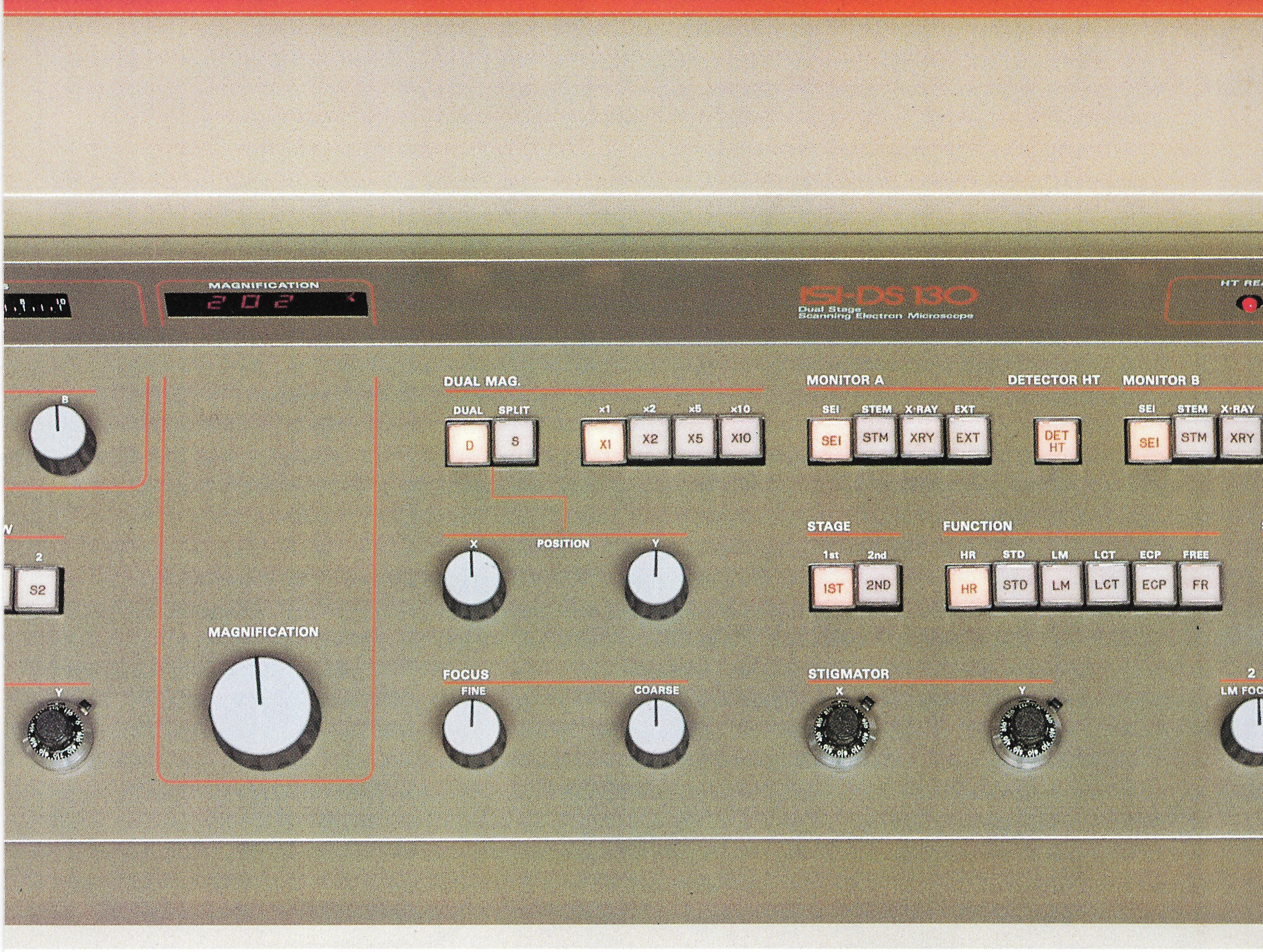
33,000X



10,000X



5,000X

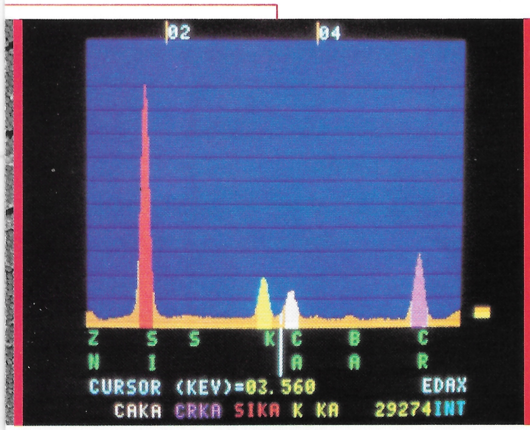


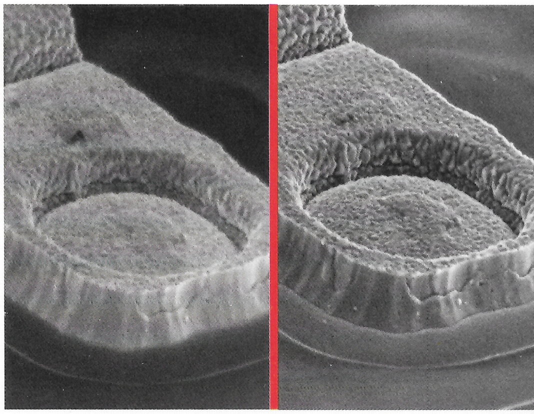
trol console. Alternatively a fully automatic exposure system (ACB) which is built into the instrument can be used. This locks in the correct levels for photography, completely independent of operator adjustment. It is therefore easy for inexperienced operators to consistently produce properly exposed micrographs using the DS-130.

Optimum Operating Conditions Assured with Function Select Buttons

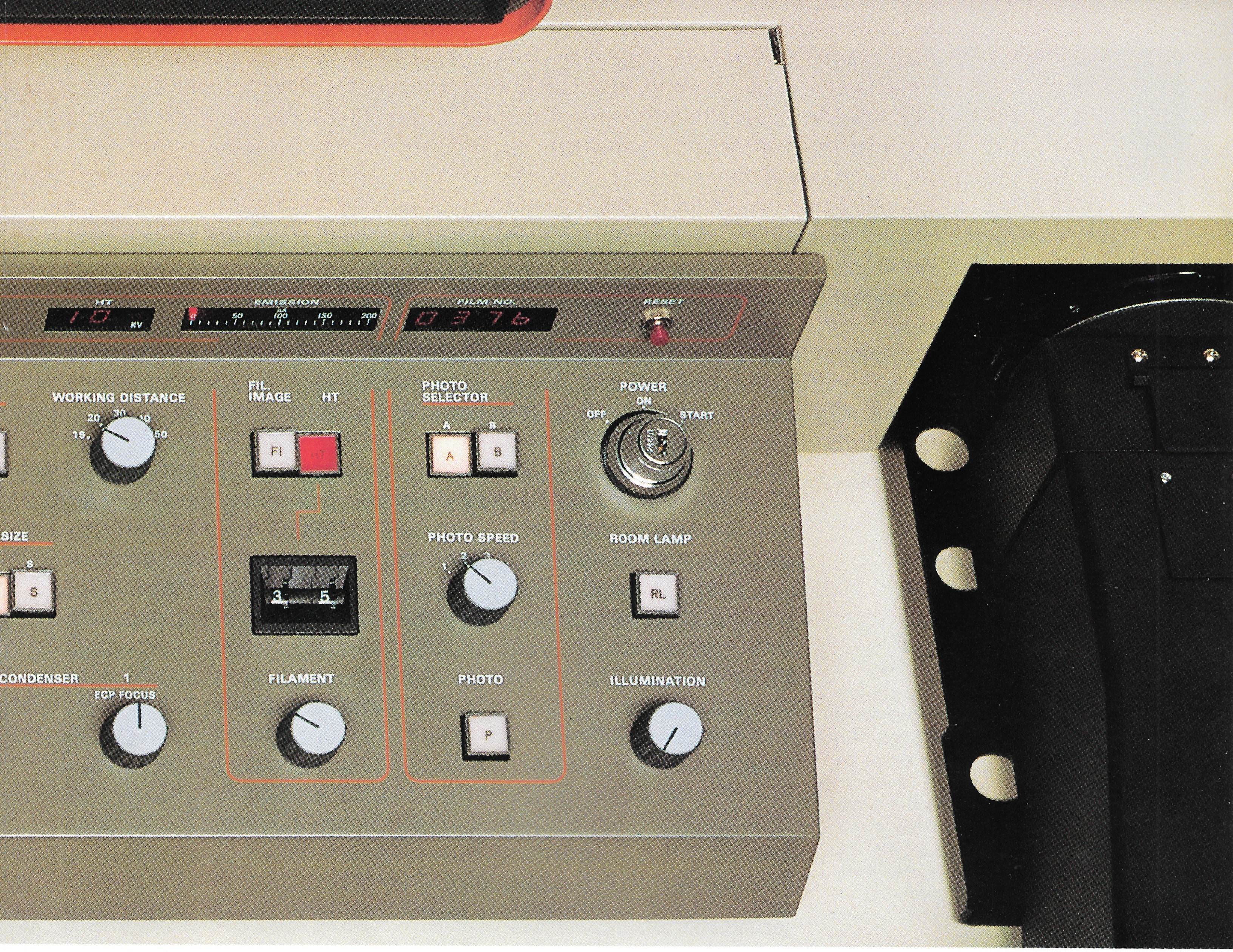
The function select buttons automatically set up the correct depth of focus, spot size, and specimen current conditions which have been stored in the computer. Examples are shown in Fig. 8.

The HR button is pressed when operating at, or above, about 30,000X magnification. The **STD** button is used when operating in the middle magnification range down to a few thousand times, and the **LM** button is depressed when operating at the lowest magnifications. The **LCT** button produces high specimen current conditions, required for backscattered electron imaging, x-ray analysis, etc. The optimum instrumental parameters for each condition are stored in the computer





• *Integrated circuit 8,600X* *1kV* *2kV*

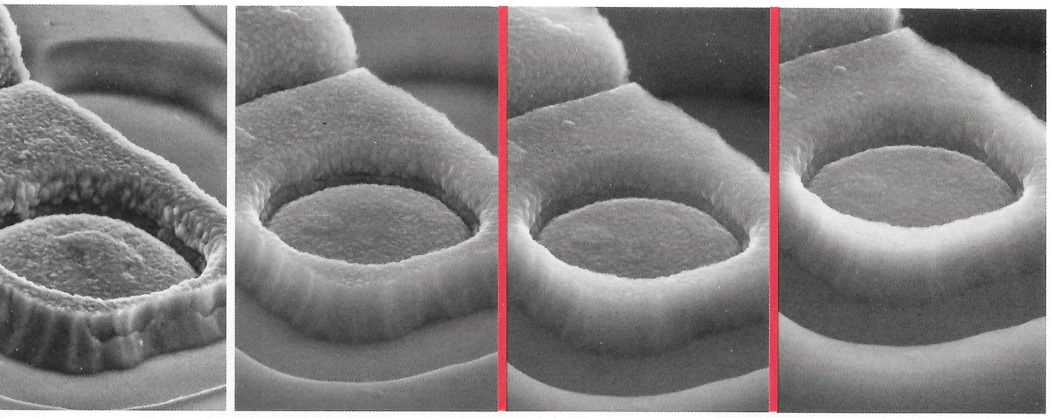


for each accelerating voltage from 1kV to 40kV. Both focus and astigmatism correction are automatically compensated on changing the function select buttons.

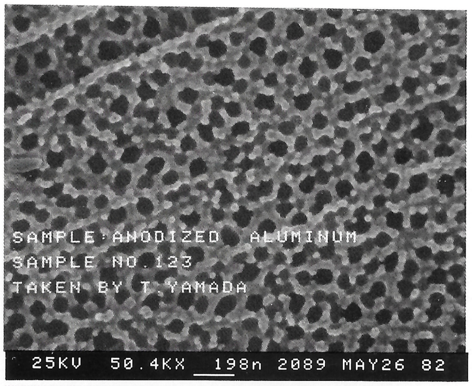
Image Recording

A 5" high resolution (2,500 lines) short persistence CRT is used for photography. The following data is automatically recorded on each micrograph: accelerating voltage (2 digits), magnification (3 digits), micron bar with digital indicator, and film number (4 digits). The film number is automatically advanced one digit every time a photograph is taken. A keyboard data entry system is available. This allows up to 13 lines (32 characters per line) of data to be entered onto the image.

A number of different types of cameras and film can be used with the instrument. These include Polaroid, roll film (60x90mm), and 35mm.



5kV 10kV 20kV 30kV



• *Character data input device (keyboard)*

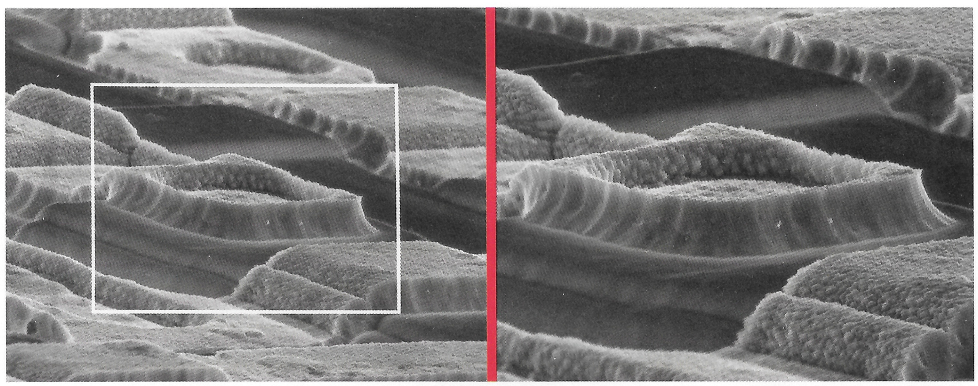
ISI DS-130 DISPLAY SYSTEM

■ Signal Processing

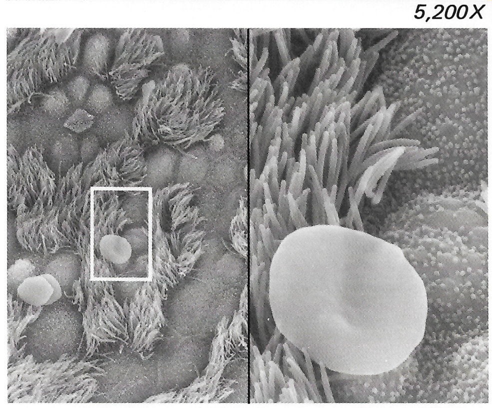
Due to the fact that SEM images are produced by scanning the specimen surface, and built-up one picture point at a time, it is possible to process the image in a number of ways not easily accomplished in static imaging instruments. For example, this allows the contrast and brightness levels to be varied without having to alter the specimen in any way.

▶ Dual Magnification

This permits two images of the same area of a specimen to be displayed simultaneously at different magnifications. The two images can be displayed separately on the two viewing CRTs, which are provided, or on a single CRT on a split screen basis. Magnification ratios of 1X, 2X, 5X, and 10X can be selected. The location of the high magnification image framed within the low magnification image is indicated by a bright frame which is movable.



5,200X *8,000X*

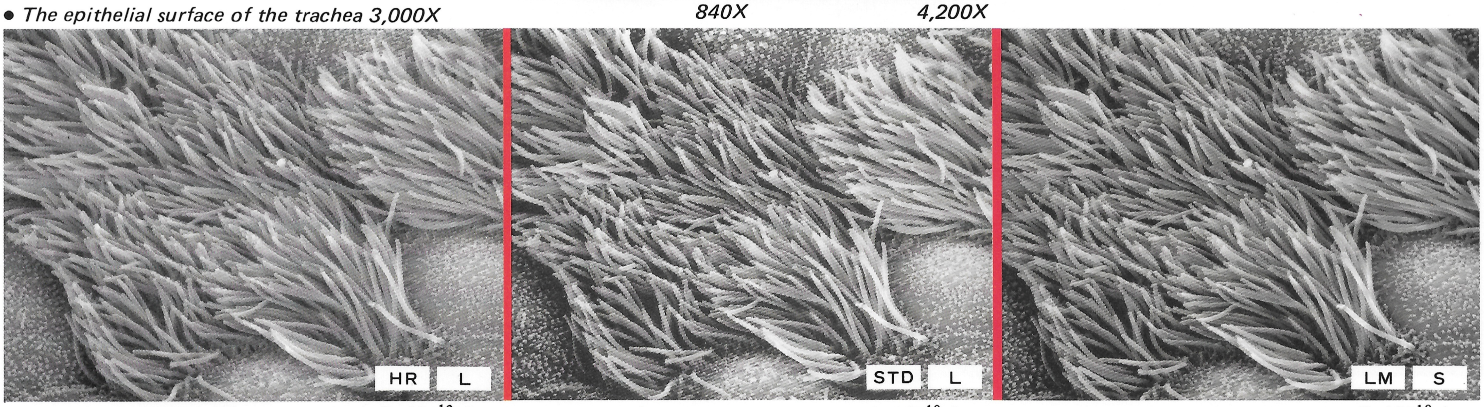


840X *4,200X*

▼ Auto Contrast and Brightness

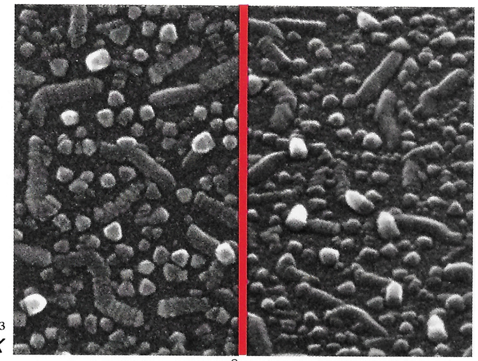
This automatically sets the correct brightness and contrast levels for photography. It can be calibrated for a variety of photo record speeds and film/camera combinations.

• *The epithelial surface of the trachea 3,000X*

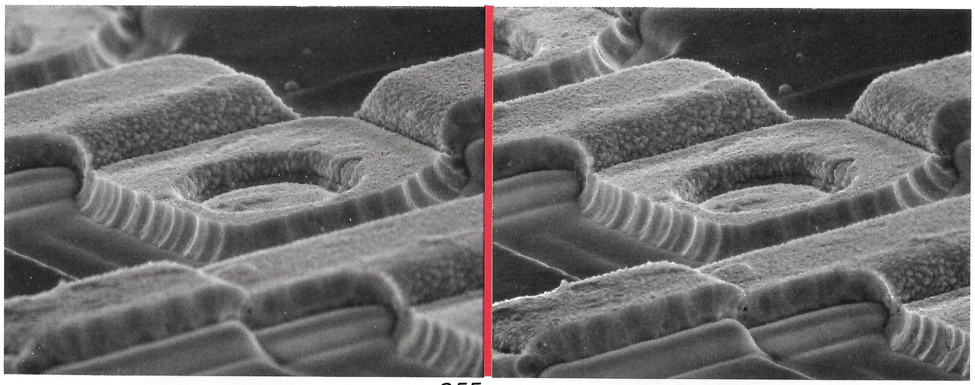


$5x10^{-12}$ Amp *$1x10^{-10}$ Amp* *$5x10^{-10}$ Amp*

• *Transparent electrode indium oxide In_2O_3*
50,000X



0° *60° tilted*

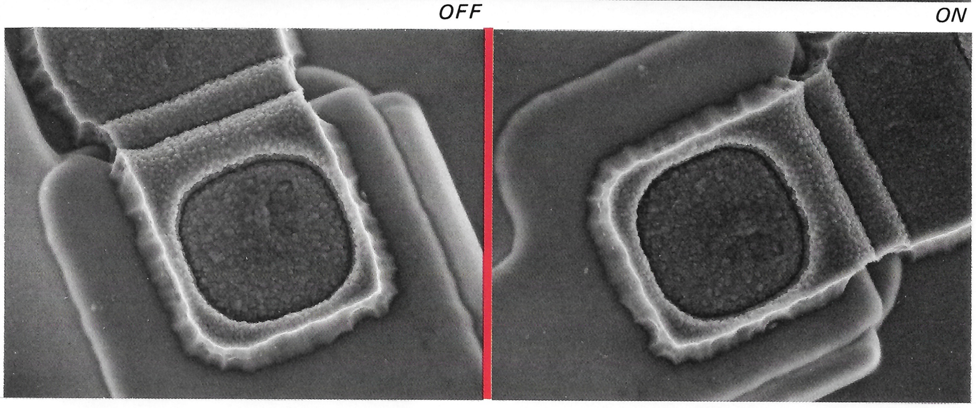


OFF *ON*

◄ Dynamic Focus

This corrects for image edge defocusing when examining a tilted specimen. It produces uniformly sharp images on specimens tilted up to 80°.

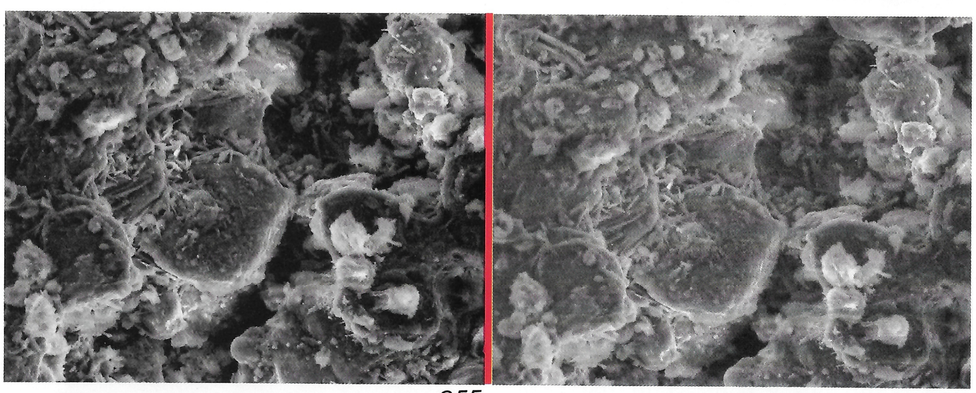
• *6,000X*



◄ Scan Rotation

The image on the screen can be rotated 360°. This is useful for properly framing an object to be photographed.

• *6,000X*

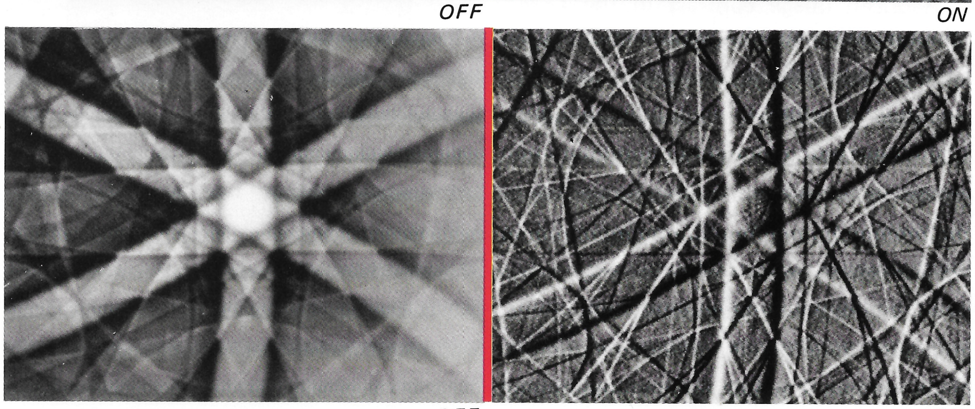


OFF *ON*

◄ Gamma Control

This control changes the response characteristcs of the video amplifier, and allows details in highlights and shadows of extremely contrasting specimens to be shown simultaneously.

• *Cement 600X*



OFF *ON*

◄ Derivative Processor

Edge contrast can be enhanced with this circuitry by differentiating the signal and mixing it in varying proportions with the normal signal. It is useful in many situations where the contrast is low.

The features described above are all standard on the DS-130.

A Broad Range of Optional Accessories Allow the Application of the DS-130 to be Extended

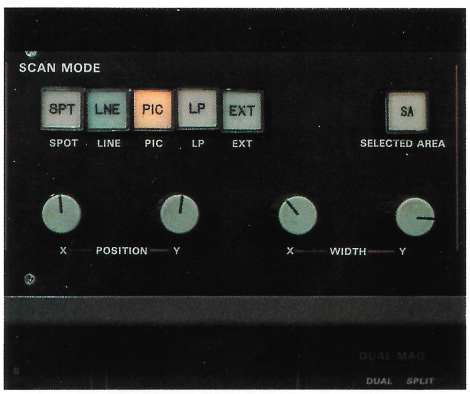
Versatility is essential in the research grade ultra high resolution SEM. The DS-130 satisfies these requirements.

■ Analytical SEM permitting the observation of microstructures down to 3nm with both qualitative and quantitative x-ray analysis capability.

The advanced five lens design, which is used in the DS-130, offers exceptional flexibility. Resolution in the secondary electron imaging mode of 3nm is readily achieved. On the other hand, exceptionally high specimen currents of up to 10^{-5} amps can be realized. This is particularly important for quantitative EDX analysis, and is an important feature for both qualitative and quantitative analysis using a wavelength spectrometer. When examining thin specimens, of the type suitable for STEM operation, qualitative resolution on an area as small as 20nm and qualitative analysis on an area of a few tens of nanometers can be performed.

The correct operating conditions for high resolution imaging and x-ray analysis are easily changed by pressing a button. Focus is maintained and astigmatism correction is compensated.

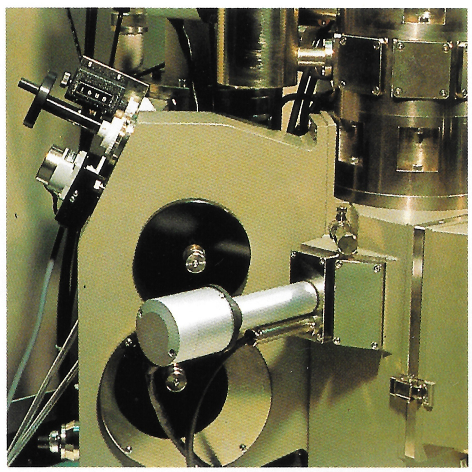
The DS-130 is provided with both spot, line and dot map distribution capabilities. A variable reduced area scan allows an x-ray map from a selected portion of the field of view to be made.



• DS-130 Scanning mode control panel

Accepts WDX and EDX Accessories

The DS-130 is designed to accept a wavelength dispersive x-ray spectrometer (WDX), and an energy dispersive x-ray spectrometer (EDX) at the same time. The WDX system is fully focusing, with a Rowland circle radius of 125mm, which assures high count rates. It is equipped with four crystagls (LiF, PET, TAP and LOD) which allow the analysis of all elements from B to U. A Be window EDX detector can analyze all elements from Na to U, while a windowless EDX detector will analyze all elements from C to U. Using the DS-130 top stage, equipped with an EDX analyzer and STEM detector, qualitative analysis from regions down to 20nm diameter can be performed. Until recently this type of high resolution x-ray analysis has been performed in TEMs operating up to about 100kV and 200kV. The analysis of light



• Bottom specimen chamber equipped with WDX

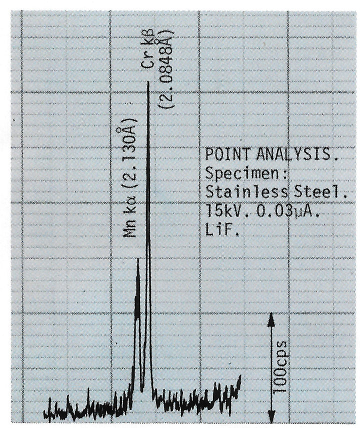
elements, such as Na and Ca, in unstained biological speciments is an important application area. Operating at voltages in the 100kV range in a TEM, however, has the following associated problems.

a) Reduced image contrast in the TEM image.
b) Reduced x-ray generating efficiency for light elements.
c) Increased background due to continuous x-rays.

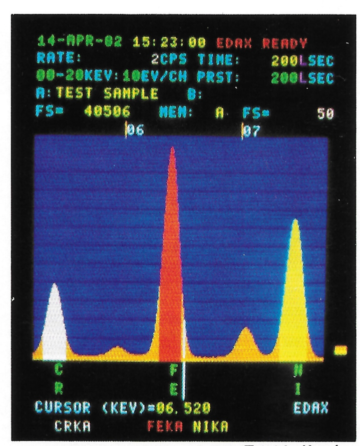
Operating at lower voltages in a TEM, comparable to that in a SEM, results in severe image degradation.

The DS-130 has been designed to produce not only high image resolution, but optimum x-ray analysis capability — especially at low accelerating voltage, which is important for light element analysis.

Careful design, involving the choice of the x-ray take-off angle, has resulted in minimum background contribution.



• WDX spectrum



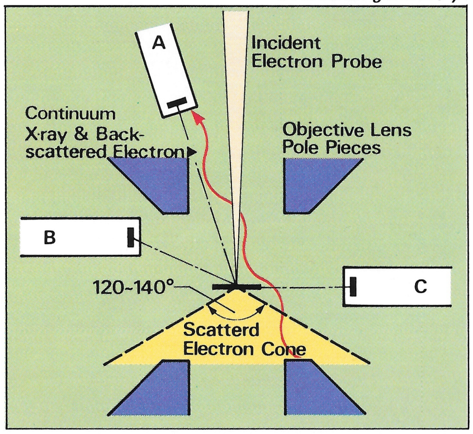
• EDX display

Optimum X-Ray Take-off Angle

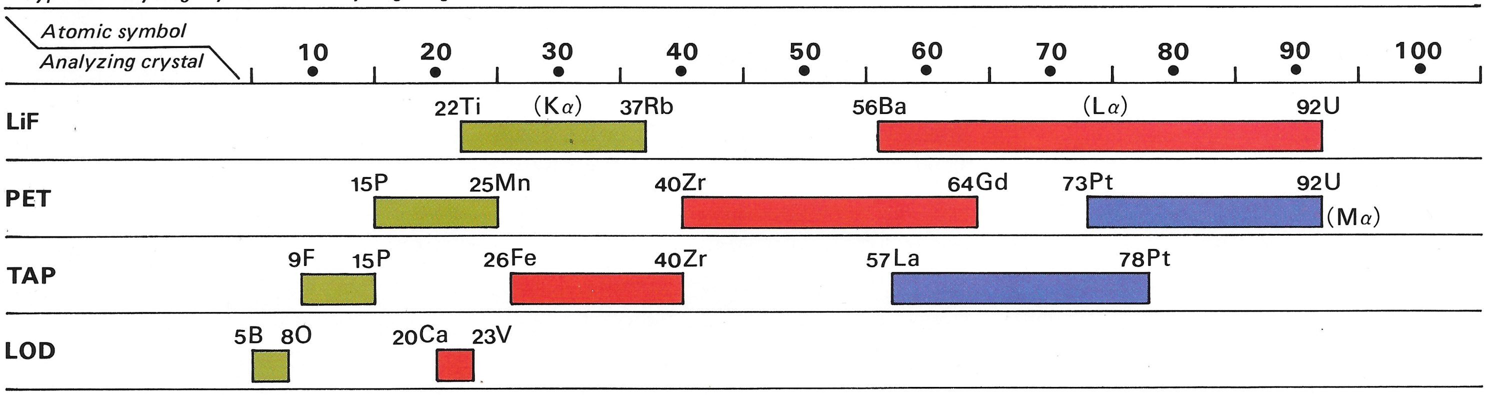
In recent years, there has been a growing interest in high resolution x-ray analysis of thin specimens, both in biology and materials science. With currently available SEMs and TEMs, there are some severe restrictions which relate to the x-ray take-off angle.

Electrons, on passing through a thin specimen, are scattered through angles ranging from 120° to 140°, as shown in Fig. 9. These scattered electrons strike the objective lens polepiece or objective aperture in a TEM, and produce a high x-ray background. If the x-ray detector is in position A, it detects both backscattered electrons and a high x-ray background. If the detector is in position C, the backscattered electrons are prevented from getting to the detector by the lens field, but the specimen must be tilted towards the detector in order to pick up x-rays. If the specimen is tilted 20° to 30° x-rays can be produced by the specimen mounting grid, which will often be within the scattered electron cone. The optimum position is therefore B, where backscattered electrons cannot reach the detector, and the specimen does not have to be tilted. Position B is the location of the EDX detector in the DS-130.

● Fig. 9 Comparison of X-ray detection geometry



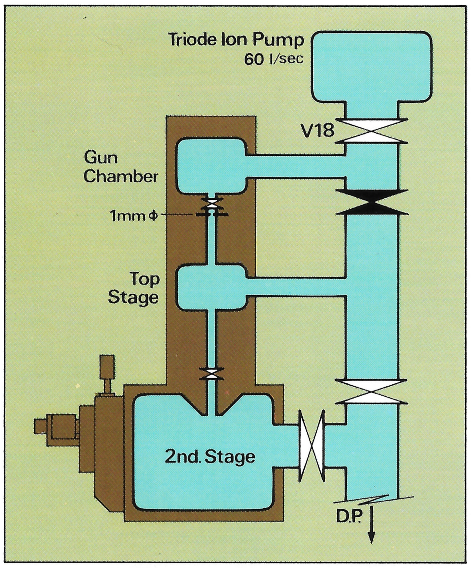
● Type of analyzing crystals and analyzing range

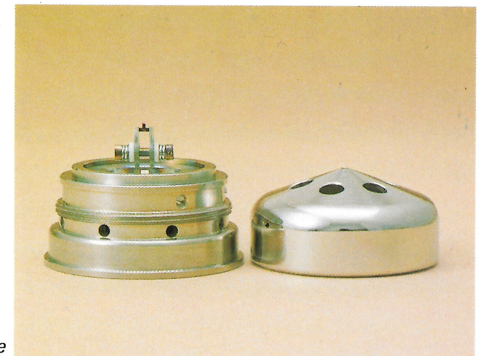


ISI DS-130 OPTIONAL ATTACHMENT

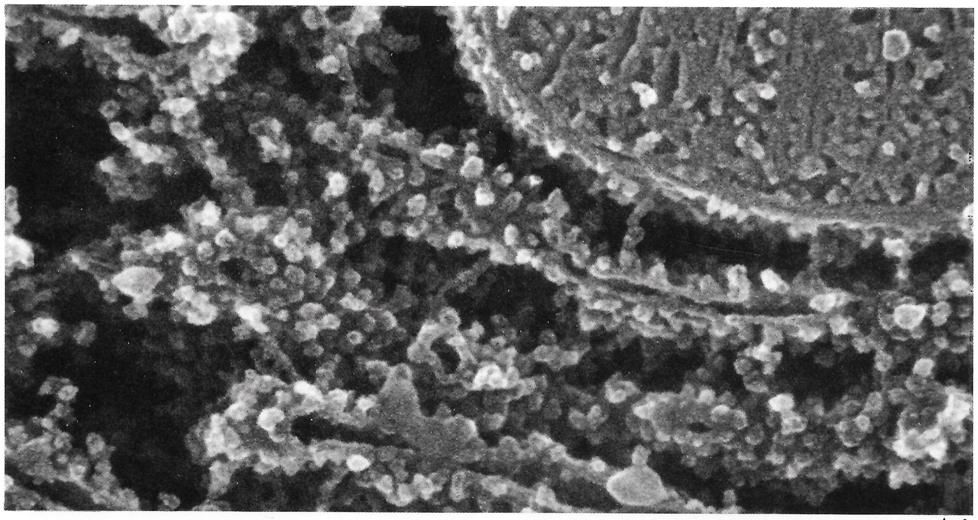
■ Single Crystal LaB_6 Electron Source (option) Assures High Gun Brightness, Long Filament Life, and a Guaranteed Resolution of 2nm (1nm possible)

The single crystal LaB_6 electron source offers a solution to the limited brightness of the tungsten hairpin filament, and the problems associated with field emission sources, which include emission instability, sensitivity to external magnetic fields and vibration, limited specimen current, and the requirement for ultrahigh vacuum.

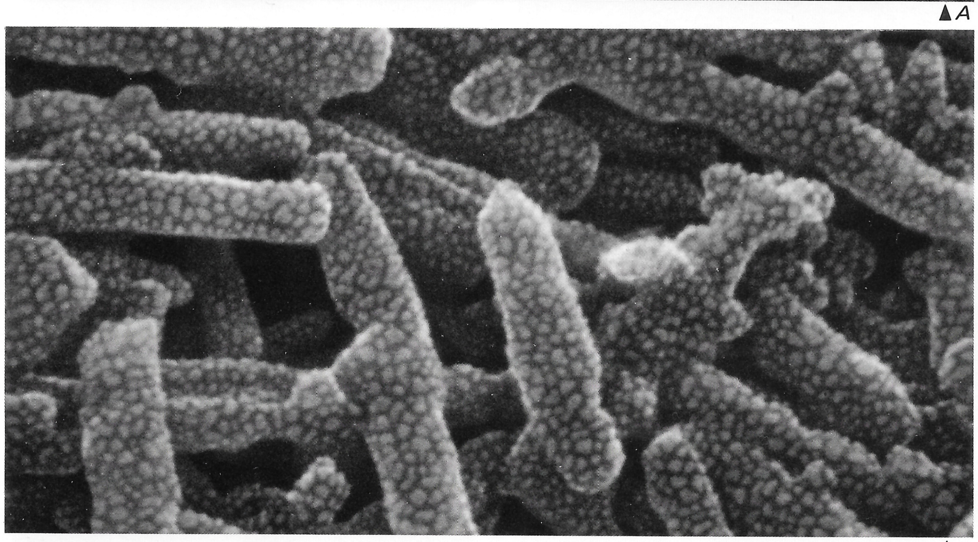




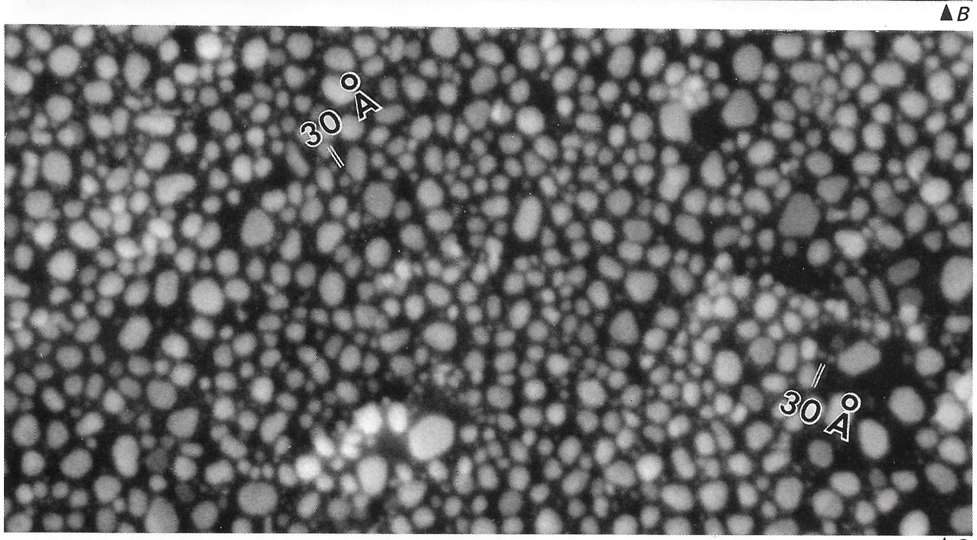
• *LaB_6 cathode*



▲*A*



▲*B*



▲*C*

The LaB_6 filament source used in the DS-130 features high brightness and a lifetime ranging typically from 500 to 1.000 hours. When combined with the strongly excited objective lens used with the DS-130 top stage, a resolution of 2nm can be realized. The single crystal LaB_6 electron source, Available for the DS-130, has very high stability and long life characteristics, due to the fact that it requires about half the power of a tungsten hairpin filament. The electron gun chamber is evacuated by a dedicated 60 ℓ/sec. ion pump. A differentially pumped aperture in the gun area allows the source to be operated continuously during such operations as specimen exchange, thus assuring optimum performance and high stability. An ion pump isolation valve (V18) avoids the need to vent the pump during filament exchange. A rapid return to operation is therefore guaranteed.

The single crystal LaB_6 filament produces higher resolution than a tungsten hairpin filament, due to its higher brightness and smaller energy spread. The latter point is particularly important for good low voltage performance. Using LaB_6 in the DS-130 produces 7nm resolution at 2kV, and 4nm resolution at 5kV, when operating in the top stage.

• *(A) Rat pancreas. courtesy of Dr. T. Inoue, Anatomy Laboratory II, Faculty of Medicine, Tottori University, Japan 110,000X*

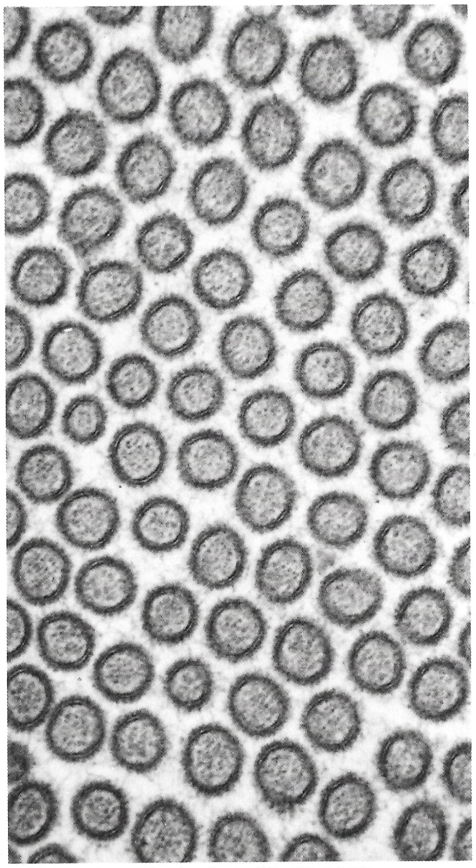
• *(B) Deposited particles of gold on magnetic tape. 170,000X*

• *(C) Deposited particles of gold on carbon. Accelerating voltage is 5kV. 85,000X*

ISI DS-130 OPTIONAL ATTACHMENT

■ STEM

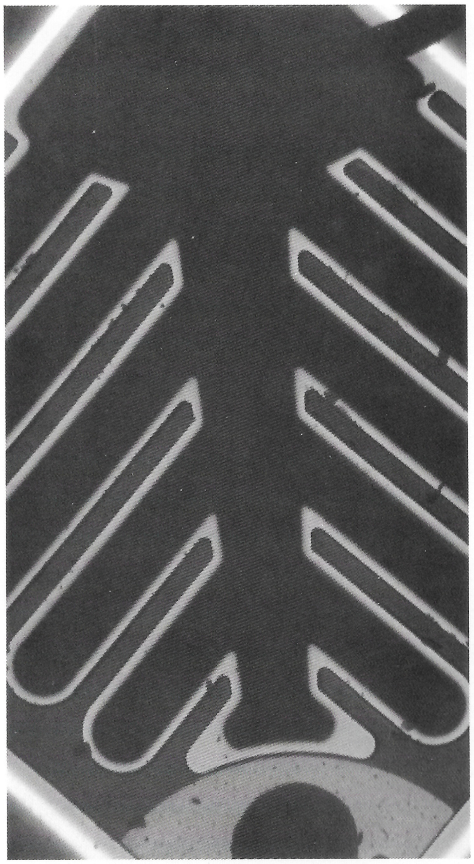
With the strongly excited objective lens used with the DS-130 top stage, it is possible to place an aperture at the back focal plane of the lens, therby allowing the production of very high contrast STEM images. As the instrument can be operated very effectively at relatively low accelerating voltages, in the range from 10kV to 15kV, light element analysis of biological specimens using an EDX detector is very efficient.



● *Mouse intestinal microvilli. 50,000X*

■ EBIC

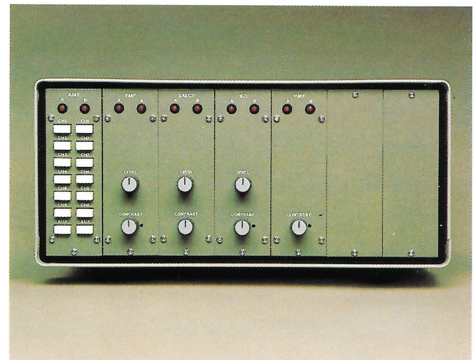
The bottom stage is equipped with a 25 pin feedthrough, which can be conveniently used for the display of EBIC and voltage contrast images.



● *Transistor 100X*

■ CRYO

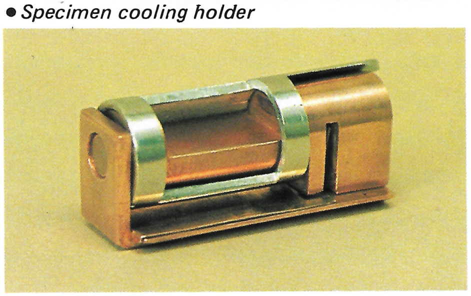
There has recently been an increasing interest in observing and analyzing frozen materials and biological specimens in the SEM. For example, applications include cement, clay, solvents, emulsions, milk products such as cheese, plants, and various organisms. With conventional equipment, there have been severe limitations imposed by the specimen chamber of the microscope. A system is available for the DS-130 which allows the specimen to be rapidly frozen outside the SEM, fractured, coated, and transferred under vacuum onto a cooled stage in the microscope. This stage is cooled to -160°C, and has an LED temperature display.



• *Accessories box*

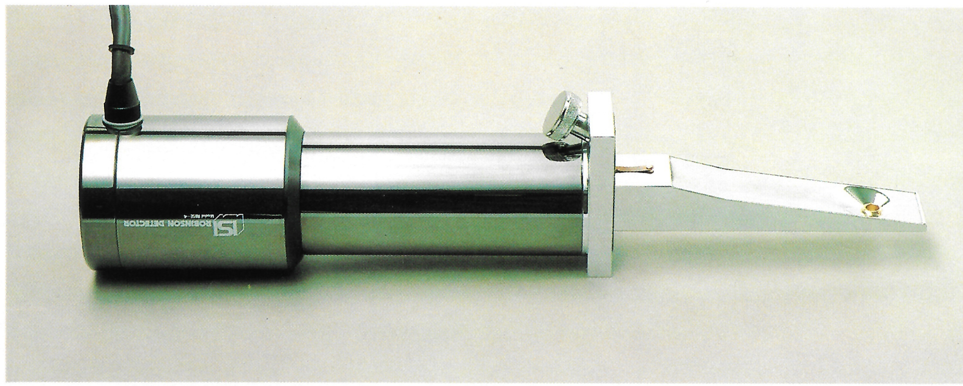
• *Phycomycete sporangia in wheat root. Matherial flozen etched and coated 250X*

• *Specimen cooling holder*



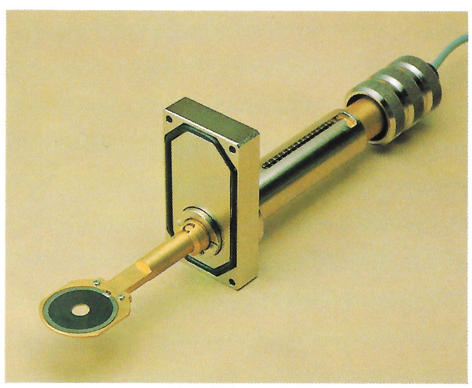
■ Backscattered Electron Detectors to Meet Varying Requirements

Backscattered electron images are characterized by enhanced elemental contrast. The images are also much less susceptible to the effects of charging than a secondary electron image. Two different types of BSE detectors are available for the DS-130 bottom stage — a high resolution Robinson detector, or an annular solid state detector. A double chip solid state detector is available for the top stage.



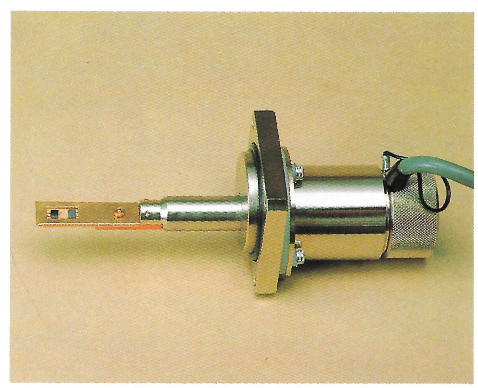
Robinson Backscattered Electron Detector (bottom stage only)

A block of plastic scintillator material is used to detect the energetic BSEs. It subtends a large solid angle, so the electron collection efficiency is very high. The detector will operate at specimen currents down to 10^{-12} amps, and produce image resolution of 10nm. Further advantages are that images can be formed with incident beam energies down to 5kV and TV type imaging is possible.



Annular Solid State Detector (Bottom stage)

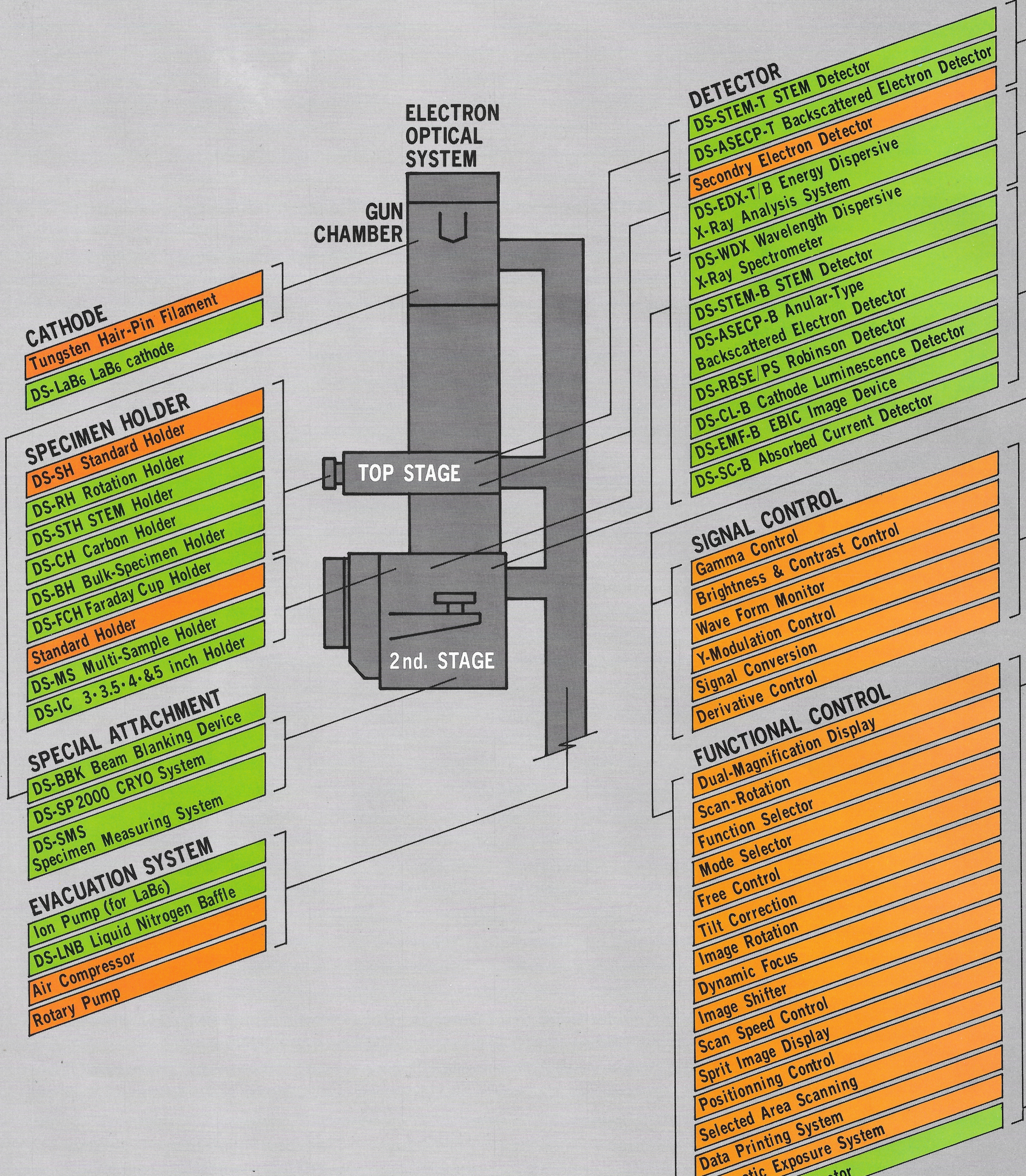
Because of its high detecting efficiency, this detector can be used for observation of atomic number contrast and electron channelling pattersn.



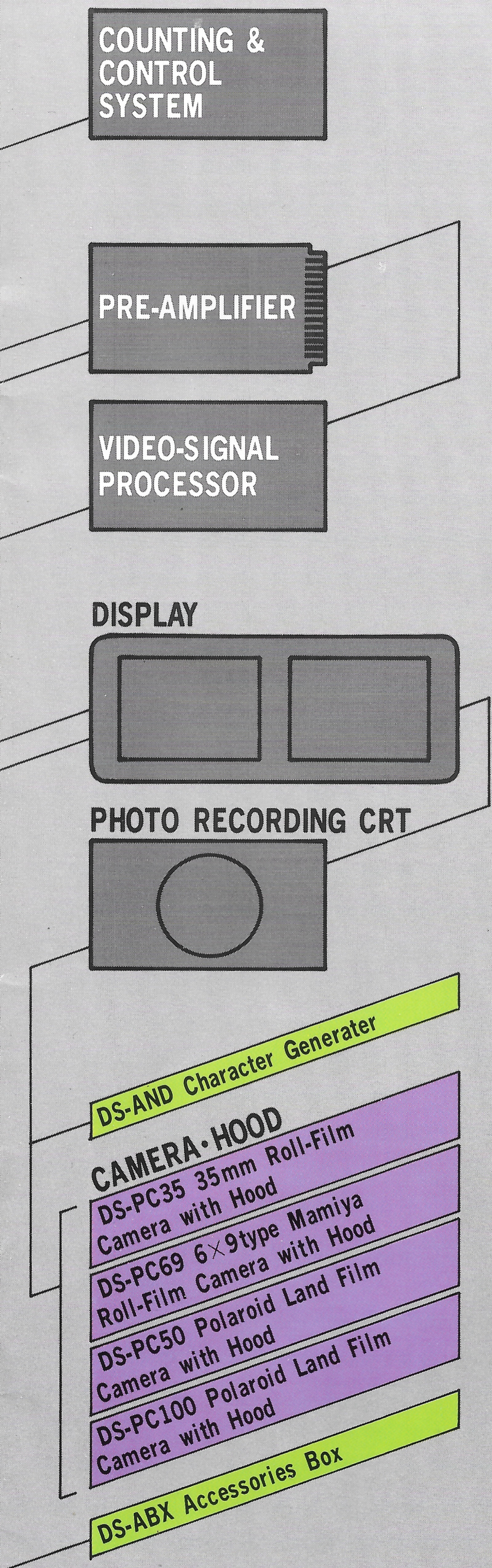
Solid State BSE Detector for the Top Stage

This can be used to produce high resolution images with the specimen in the top stage. It is particularly useful for producing channeling patterns. Such patterns can be obtained from areas as small as 2 to 3 microns, a rocking angle up to 30°.

ISI DS-130 BLOCK DIAGRAM



: *Standard equipment*
: *Special Accessories*
: *One of these is standard and should be specified on order.*



Column Cleaning Required Only Once Per Year

Optimum Performance Assured at all Times

The entire column of the DS-130, including the electron gun, lenses, and specimen chamber, has been designed with minimum contamination as an important goal. The achievement of this, allows the instrument to be operated for up to a year without having to clean the column. When a specimen is irradiated with electrons in a SEM, contaminants are emitted which collect on various surfaces close to the specimen, including the very critical objective aperture. When operating with a specimen in the DS-130 top stage, an aperture located just below the second condenser lens is used as the objective aperture. As this is far from the specimen location, and it does not become rapidly contaminated. The image of this aperture is greatly demagnified by the high field strength objective lens. The influence of aperture contamination is reduced by about 100 times compared to the conventional objective lens configuration. This is one important reason why the DS-130 requires very infrequent cleaning. When operating with a specimen in the bottom stage, the second condenser aperture is also used to define the beam convergence angle. Again the aperture is shielded from contamination by the specimen, and any astigmatism introduced by the aperture is decreased by the demagnification of the mini lens.

These unique features considerably extend the time periods between which routine column maintenance is required, compared to conventional SEMs.

Easy Column Maintenance and High Reliability

Only three column components require cleaning periodically on the DS-130 — the second condenser aperture, column liner, and mini objective lens aperture. These are easily removed without having to dismantle the column. As this maintenance is required only about one per year, high resolution performance is obtained on a routine basis.

By using computer control, the number of relays, which are a common source of problems in electronic circuitry, are much decreased. By incorporating a wide range of signal processing capabilities, such as scan rotation/tilt correction, and dynamic focus, etc., as standard features, it has been possible to simplify circuitry and thereby further increase reliability.

ISI DS-130 SPECIFICATIONS

● PERFORMANCE

		TOP STAGE	BOTTOM STAGE
RESOLUTION W Filament	Secondary Electron STEM (option)	30Å (3nm) 25Å (2.5nm)	60Å (6nm)
LaB_6(option)	Secondary Electron STEM (option)	20Å (2nm) 15Å (1.5nm)	50Å
MAGNIFICATION	Secondary Electron STEM (option)	20X-300,000X, 36 steps 300X-300,000X, 25 setps	10X-300,000X, 36 steps
ACCELERATING VOLTAGE		1-40kV in 1kV steps	

● KINDS OF IMAGES

	TOP STAGE	BOTTOM STAGE
STANDARD	SE, Channeling	SE, BSE
OPTIONAL	BSE (solid state detector) STEM X-ray map	BSE (Robinson and annular solid state detector) Cathodoluminescence STEM X-Ray map (WDX, EDX) EBIC Specimen Current

● ELECTRON OPTICS SYSTEM

ACCELERATING VOLTAGE .... 1-40kV in 1kV steps
ELECTRON GUN .... Tungsten hairpin filament (precentered), LaB_6 (option)
GUN ALIGNMENT .... Horizontal and tilt (2 stage) electromagnetic deflection)
CONDENSER LENS SYSTEM ...... 3 stage. Double gap 1st condenser and single gap 2nd condenser
CONDENSER LENS APERTURE 30, 50, 100, 200μm changeable
STIGMATOR .... 8 pole electromagnetic (centerable)
IMAGE SHIFT .... ±5μ in X, Y directions (top stage) ±25μ in X, Y directions (bottom stage)
OBJECTIVE LENS .... Dual objective lenses. Strongly excited lens (top stage). Mini lens (bottom stage). W.D. 8-53 with automatic mag. compensation.
OPERATING FUNCTIONS .... High Resolution, Standard, Low Magnification, Large Current, ECP, Free, and External Control

● SPECIMEN STAGE

		TOP STAGE	BOTTOM STAGE
SPECIMEN SIZE		8mmφ x 5mm (Large specimen size 8mmφ x 9mm)	102mmφ x 25mm 102mmφ x 0.5mm (4" IC Wafer) 76mmφ x 25mm 32mmφ x 25mm 15mmφ x 15mm
TILT ANGLE		$-5^\circ \sim +95^\circ$	$-10^\circ \sim +70^\circ$
ROTATION		$0 \sim 360^\circ$ (option)	$0 \sim 360^\circ$
SPECIMEN MOVEMENT	X Direction	6mm	56mm
	Y Direction	6mm	56mm
	Z Direction		8 ~ 53mm
VIEWING AREA		$36mm^2$	$3{,}136mm^2$ $8{,}160mm^2$ using rotation
SPECIMEN EXCHANGE		AIRLOCK	Hinged door with 25 pin and BNC Connector
ANTICONTAMINATION DEVICE		LN_2 cooled Cold finger	

● SCAN CONTROL

SCAN MODES .... Viewing, Reduced Area, Line, Spot, Y-Modulation
SCAN SPEEDS .... Viewing
Rapid-1 : 0.06 sec
Rapid-2 : 0.1 sec (reduced)
Slow-1 : 5 sec
Slow-2 : 10 sec
Photo 40, 80, 160, 320 sec (2,500 lines)
Reduced Area
Total area of 12" CRT (max)
10 x 10cm area on 12" CRT (min)
Position Anywhere on 12" CRT
DUAL MAGNIFICATION X1, X2, X5, X10
SPLIT SCREEN X1, X2, X5, X10
SCAN ROTATION .... $0^\circ \sim 360^\circ$ continuous
DYNAMIC FOCUS .... $0^\circ \sim 80^\circ$
TILT CORRECTION .... $0^\circ \sim 80^\circ$
VIEWING CRT .... 12" long persistence, 2 ea.
PHOTO CRT .... 5" short persistence, ultrahigh resolution (2,500 lines)
SIGNAL PROCESSING .... Gamma, Brightness/Contrast, Signal Inversion, Waveform Monitor, Dynamic Focus
ADJUSTING EXPOSURE .... Independently displayed contrast and brightness on LED indicators. Automatic Contrast and Brightness adjustment.
CAMERAS .... Polaroid or roll film
DATA RECORDING .... Accelerating Voltage, Magnification, 4 digit film number (automatically advanced each photo), micron bar, bar length.

● VACUUM SYSTEM

OPERATION .... Fully automatic
GUN ISOLATION VALVE .... Provided
COLUMN ISOLATION VALVE .... Provided
ROUGHING PUMP .... 160 ℓ/min
OIL DIFFUSION PUMP .... 600 ℓ/sec
RESERVOIR TANK .... 1 ea.
AIR COMPRESSOR .... 1 ea.
WATER COOLED BAFFLE .... 1 ea.

● SAFETY INTERLOCKS

Operate in the event of vacuum, power, and cooling water failure.

■ ACCESSORIES

● DS-STEM-T Scanning Transmitted Electron Imaging System for Top Stage

RESOLUTION 25Å (2.5nm)
SPECIMEN MOVEMENT .... X-Y ±1mm (up to ±3mm possible)
SPECIMEN TILT .... $-5^\circ \sim +95^\circ$
SPECIMEN SIZE .... 3mmφ mesh
ELECTRON DETECTOR .... Scintillator photomultiplier

● DS-STEM-B Scanning Transmitted Electron Imaging System for Bottom Stage

RESOLUTION 50Å (5nm)
ELECTRON DETECTOR .... Scintillator photomultiplier

● DS-SAECP-T Backscattered Electron Imaging Device for the Top Stage

ELECTRON DETECTOR .... Solid State — Double Chip
CONTROL .... Brightness and Contrast
Allows high resolution electron channeling patterns to be produced in the top stage.

● DS-SAECP-B Backscattered Electron Imaging Device for the Bottom Satge

ELECTRON DETECTOR .... Solid State ring
CONTROL .... Brightness and Contrast
Allows electron channeling patterns to be produced in the bottom stage.

● **DS-EDX-T/B** Energy Dispersive X-Ray Analyzer
Allows qualitative and quantitative analysis to be performed. Using Be window detector all elements from Na to U can be analyzed. The detection limits for a windowless detector extend the range from C-U. All currently available EDX systems can be fitted to the DS-130 in either the top stage or bottom stage.

● **DS-RBSE/PS** Robinson Backscattered Electron Imaging System

PROBE CURRENT	All probe currents down to 10^{-12} amps

● **DS-CL-B** Cathodoluminescence Detector
Detects light induced by the incident electron beam on a suitable sample. Detector is glass light guide and photomultiplier.

● **DS-EMF-B** EBIC Imaging System
This shows contrast at junctions in solid state devices. The specimen is biased using the 25 pin electrical feedthrough on the bottom stage.

● **DS-SC-B** Specimen Current Imaging Device

BANDWIDTH	1 kHz
INPUT CURRENT	$10^{-7} \sim 10^{-10}$ Amps

● **DS-WDX** Wavelength Dispersive Analysis System

WAVELENGTH RANGE	0.906Å ~ 71.7Å
ANALYSIS METHOD	Diffracting crystal
ROWLAND CIRCLE RADIUS	125mm
NUMBER OF CHANNELS	1
CRYSTALS	LiF, PET, TAP, LOD (mounted simultaneously)
X-RAY DETECTOR	Wide detection range gas flow proportional counter.
DETECTION LIMITS	C and 0 : 0.04%
ELEMENTAL RANGE	B-U
PROBE CURRENT RANGE	$10^{-5} \sim 10^{-13}$ Amp (with tungsten filament)
PROBE CURRENT STABILITY	±0.2%/hr.

● **DS-ABX** Accessory Box

UNIT ACCOMMODATION	Up to 7 units including AMS unit plus 6 accessory units
DIMENSIONS	366 x 132 x 320mm

● **DS-AMS** Accessory Mode Select Unit

NUMBER OF CHANNELS	2
SELECTABLE MODES	SC, EBIC, CL, SAECP, RBSE, STEM, AUX

● **DS-AND** Character Display Unit

TYPE OF CHARACTER	ASCII code 5 x 7 dot matrix
CHARACTER GROUPS	Alphabet in capitals and small letters, numbers, symbols. 64 different characters.
NUMBER OF CHARACTERS	32 characters per line. 13 lines (write and erase). 8 characters can be added at the bottom of the micrograph in the standard print out area.

● **DS-SMS** Specimen Measuring Unit

SCALE DISPLAY	Both X and Y directions
VERNIER	Divides measurement grid into 5 equal subdivisions. Can be moved anywhere within field of view (scale vernier can be erased independently in both directions).
μm DISPLAY	Digital LED display of grid spacing. Accuracy ±1.0%

● **DS-LaB$_6$** Lanthanum Hexaboride Cathode

TIP	Single crystal
VACUUM	5×10^{-7} Torr (6.67×10^{-5} pa)
BRIGHTNESS	X10 greater than tungsten hairpin
LIFETIME	Greater than 500 hours

A good operating vacuum is assured using an ion pump for the electron gun.

● **DS-BBK** Beam Blanking System

● **DS-LNB** Liquid Nitrogen Baffle

CAPACITY	2.5ℓ

● **DS-SP2000** Sputter Cryo System

● **DS-PC35** 35mm Roll Film Camera Hood

● **DS-PC69** 6 x 9 Roll Film Camera Hood

● **DS-PC50** Camera Hood for 50 Series Polaroid Sheet Film

● **DS-PC100** Camera Hood for 100 Series Polaroid Pack Film

■ INSTALLATION REQUIREMENTS

● ROOM REQUIREMENTS

FLOOR AREA	2,800(W) x 2,800(D)mm
DOOR WIDTH	750mm minimum
DOOR HEIGHT	1,800mm minimum (2,000mm if LaB$_6$ system)
FLOOR LOADING	200kg/m^2 minimum
ROOM TEMPERATURE	5 ~ 40°C
HUMIDITY	Less than 60%

● POWER

200/210/220/240V single phase 3.5kVA (5kVA peak)

● COOLING WATER

SUPPLY	Flow rate: 2ℓ/min. minimum Perssure: 1 ~ 5kg/m^2 (5kg/m^2 max) Water temp: 5 ~ 20°C Hose diameter: 11mmφ I.D. (high pressure water hose with valve)
DRAIN	30mmφ I.D. minimum

● STRAY MAGNETIC FIELD

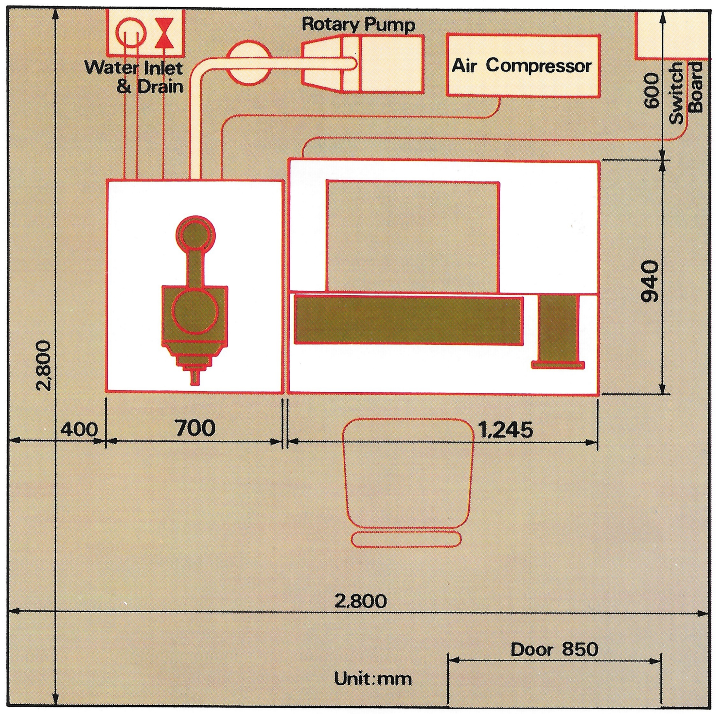
AC FIELD	Less than 3mG
DC FIELD	Less than 10mG

● VIBRATION

Less than 3×10^{-4} G (0.3 gal, 3μm 5Hz)

● SIZE AND WEIGHT

COLUMN	1,660mm(H) 700mm(W) 850mm(D) 450kg
CONSOLE	1,245mm(H)1,245mm(W)940mm(D) 300kg



● *Specifications subject to alteration without notice.*

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